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Technical recommendations in effect

BOOK N 30
(Edition 2019)

Possibilities to improve visual rope inspection (VI)

OITAF

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O I T A F

BOOK 30

Edition 2019

Possibilities to improve visual rope inspection (VI)

Written by Work Committee No. II

Content

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1 Introduction

Summary: This booklet describes the state of the art for carrying out the visual rope inspection in order to assure the safety of ropeway ropes. It also gives recommendations to improve the situation.

Visual rope inspection (VI): *The visual rope inspection is a test procedure carried out by the cableway operator. This publication describes the inspection procedure for inspection types A and C.*

In the future, the standard prEN 12927 will give three types of inspections, which will specify the speed during an inspection. Table 1-1 specifies the three types according to prEN 12927. “A type C visual inspection can be used instead of a type A inspection as an extraordinary inspection of any kind of rope in order to locate a major defect. When a type C visual inspection is used for an extraordinary inspection, it does not reset the counter for the next inspection interval.” [1]
This recommendation focuses on Type A and C only and discusses the visual inspection of hauling ropes, carrying hauling ropes and track ropes. Infrastructure ropes for example will not be covered.

Table 1-1: Inspection types according to prEN 12927 [1]

Parameter	Type A	Type B	Type C
Speed	< 0.3 m/s	0	< 1 m/s
Stop on demand	yes	Not applicable	yes

1.1 Context and scope

This booklet has been written for ropeway operators, rope and ropeway manufacturers, as well as rope inspection companies, splicers, and more generally for the large community of people interested in ropes.

Suppose there would be a survey among cableway operators with simple questions such as:

- What do you think of visual rope inspection?
- To what extent do you trust your results?

Most of the answers would be close to the following opposing poles:

“ *The visual rope inspection (VI) is time consuming and cannot be carried out* ”

“ *The VI provides reliable results; I know the condition of my ropes* ”

This booklet will:

- Describe the inspection procedure in the sense of "best practice"
- Describe the assessment of the VI conditions per workplace and the possibilities of documentation
- Provide guidance on improving the detection rate and therefore the quality of the VI-method.

The main aim of this book is to enable all the readers to recognize the importance of the VI and to do it in a proper way.

1.2 Historical overview

In previous years, the visual rope inspection was the only way to assess the condition of a rope. With the arrival of the magnetic rope testing (MRT)[1] in the 1950s the visual rope inspection was increasingly neglected, although this was prescribed in national and international regulations and standards.
Incidents and interruptions of ropeway operation led to reconsider the issue of VI over the last years. Although the EN 12927 or possibly other standards and regulations specify the inspection intervals, however the procedure is not described in detail.
This booklet aims to fill this gap.

1.3 Differentiation to Magnetic Rope Testing (MRT)

Visual rope inspection is used to detect surface damages and to determine the current condition of the outer rope layer. Surface damages, which should be detected during visual rope inspection as well as its causes and effects, will be explained further in the following chapters.
Magnetic rope testing (MRT) is suitable to detect inner wire breaks and wire breaks that lie hidden in strand touching zone. For MRT the rope gets magnetized along its axis until magnetic saturation. If there are damages in the rope, for example wire breaks or local imperfections, these damages cause a change in the leakage field. [2, 3] Visual rope inspection could be preventive because damages can be detected before wire breaks occur as a final stage. [4]
To guarantee a long lifetime of the rope it is recommended to strive for a combination of visual rope inspection and Magnetic Rope Testing (see Table 1-2). [2, 5]

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[1] For more information: OITAF Work-Committee No II, *Book 3 - Survey of Magnetic Rope Testing of steel wire ropes*

Table 1-2: Combination of Visual Rope Inspection and MRT [2]

Magnetic Rope Testing	Combination	Visual Inspection
Inner wire breaks Wire breaks in strand touching zone	Heavy corrosion Heavy wire damaging Outer wire breaks Former clamp areas Lightning strike	Twisted wires Hair lines, notches, scratches Touching of strands Beginning corrosion Wire Distortion Disturbance in rope symmetry

2 Necessity of visual rope inspection

As already mentioned in the previous chapter visual rope inspection is suitable to detect changes and damages at the rope surface. As shown in Table 1-2, it is not possible to detect all surface damages with MRT-Testing before they reach a high extent of damage.
Following, examples of risks, which can be caused by surface damages and of consequences, which can occur, are shown.

Case 1: Slipped mounting clamp
This case shows that a slipped mounting clamp can cause huge damages (e.g. by friction martensite) through surface embrittlement leading to wire breaks, if the damage is not detected in time. Since visual rope inspection was not executed, the damage, which occurred at a length of 41 cm, had not been detected until the next MRT-Testing. The loss of metallic-area has already reached 40 % in the reference length of 30 d.

Figure 2-1:Damages of slipped mounting clamp

Figure 2-2:Damages of slipped mounting clamp

Case 2: Sunken tuck tail ends

In this case a shrunken tuck tail end was not detected and lead to wire breaks in the strand touching zone. As the damage was detected, a regular restructuring was not possible any-more and an additional strand had to be spliced-in. The rope had to be replaced soon after that occurrence.

Figure 2-3: Shrunken tuck tail ends with several wire breaks

Case 3: Damages by current flow

Current flow can cause huge rope damages. Whereas Figure 2-4 and Figure 2-5 show com-paratively small damages, Figure 2-6 and Figure 2-7 show massive damages caused by cur-rent flow. If current flow occurs, an unscheduled inspection has to be executed to detect pos-sible damages immediately and initiate repair measures, if necessary. Even apparently small damages can have a great impact, if they are not detected and can lead to discard criteria.

Figure 2-4: Damage by current flow

Figure 2-5: Damage by current flow

Figure 2-6: Damage by current flow

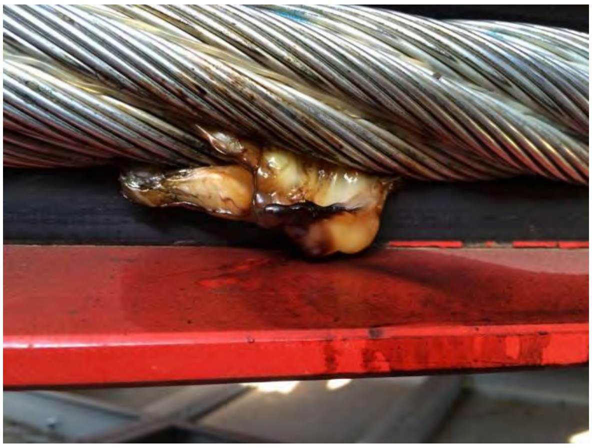


Figure 2-7: Damage by current flow

Case 4: Track rope damage

Figure 2-8 shows track rope damage where profiled wires came out of the rope. The damage occurred during the moving process of the track rope when it suddenly slipped over a steel saddle with small D/d-ratio.

The rope was mechanically damaged during the slipping. Figure 2-9 shows fretting marks, grinding and corrosion marks. Caused by hydrogen induced stress corrosion in the area of the damage forced ruptures occurred, caused by micro cracks. The damages did not show up during MRT-Testing. [6]

The fundamental finding of this accident is that the rope surface has to be thoroughly inspected after moving the rope to detect and repair damages early.

Figure 2-8: Track rope damage [6]

Figure 2-9: Track rope damage – detail [6]

Case 5: Lightning strike

Figure 2-10, Figure 2-11, Figure 2-12 and Figure 2-13 show damages caused by lightning strikes on stranded ropes and locked coil ropes in various extent of damage.

Figure 2-14 shows the point of impact of a lightning strike at a track rope at the bottom of the rope. The point of discharge is shown in Figure 2-15. Both places did not show any visible wire damage, however, MRT-Testing showed inseparable, asymmetrical amplitudes, which would usually indicate two inner wire breaks. Although the position was mentioned in the report, its risk potential was only detected at a second MRT-Testing, which also included a random visual inspection. Operation had to be stopped afterwards and the rope had to be replaced since the attempt of repairing the rope failed.

Lightning strike can lead to loss of wire material, sharp-edged surfaces and structural changes such as martensite and therefore will gradually cause wire breaks (detailed description see chapter 4.3.1). If it is known that lightning strikes often occur at an installation, an unscheduled visual rope inspection has to be performed to detect possible damages after every thunderstorm.[2]

Figure 2-10: Lightning strike at strand rope

Figure 2-11: Lightning strike at locked coil rope

Figure 2-12: Lightning strike with huge damage at strand rope

Figure 2-13: Lightning strike at locked coil rope

[2] Compare §13.3.5 “Extraordinary inspection“ prEN 12927

Figure 2-14: Point of impact at the underside of the rope

Figure 2-15: Point of escape at the side of the rope

3 Current situation of inspection conditions

3.1 General

The current conditions for visual rope inspections are often insufficient, especially regarding the workplace environment.

- Often, there are very confined conditions at the rope (compare Figure 3-1) or the inspection has to take place on ladders (compare Figure 3-2)
- Inspectors have to sit or stand in uncomfortable positions for a long period of time (compare Figure 3-1)
- Sometimes only one inspector is carrying-out the inspection, using a mirror to simultaneously see the bottom of the rope[3]
- During the inspection of track ropes special attention has to be paid to safety precautions (compare Figure 3-8 to Figure 3-11)
- There are bad illumination conditions – the weather can have a negative impact by sun, fog, snow or rain (compare Figure 3-3)

Additional inspections often take place without any breaks. This demands a huge ability to concentrate from the inspector. If the concentration decreases, there is a risk of missing damages that would lead to discard criteria at further operation.

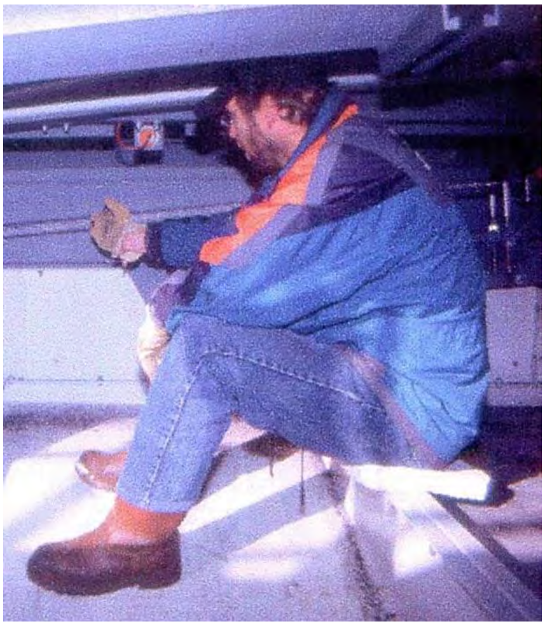


Figure 3-1: Uncomfortable seating position during an inspection

Figure 3-2: Visual inspection on a ladder and a small platform

[3] See important information on page 15

Figure 3-3: Fog during track rope inspection

Next to confined space conditions that are shown in Figure 3-1 and Figure 3-2 there are also installations, which are equipped with special seats or benches for visual rope inspection and therefore allow more comfortable working conditions. Examples are shown in Figure 3-4 and Figure 3-5.

Figure 3-4: Special chair for inspections

Figure 3-5: Special equipments for visual inspection

Commonly, two inspectors perform visual rope inspection of track ropes, carrying hauling ropes or hauling ropes. However, even if two people inspect the rope it is not possible to inspect the whole surface of the rope.

For clarification, see Figure 3-6. The green part of the rope is visible during inspection and the red part of the rope is in the blind spot of the inspectors.

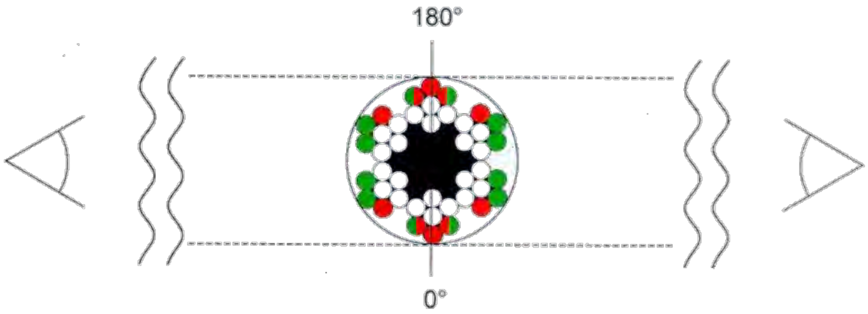


Figure 3-6: Visible part of the rope surface during visual rope inspection

Additional to the inspection with two people, variations of two people using an additional mirror or one person using an additional mirror are sometimes used to perform visual rope inspection. All three combinations are shown in Figure 3-7.

> *Important information: If only one person is doing an inspection, the inspection has to be executed <u>twice</u>. The first time: to inspect the upper half of the rope. The second time: to inspect the bottom half of the rope (with the help of a mirror). This method should only be used during track rope inspection* because of the inevitable rotation of the rope while going over rollers and sheaves.

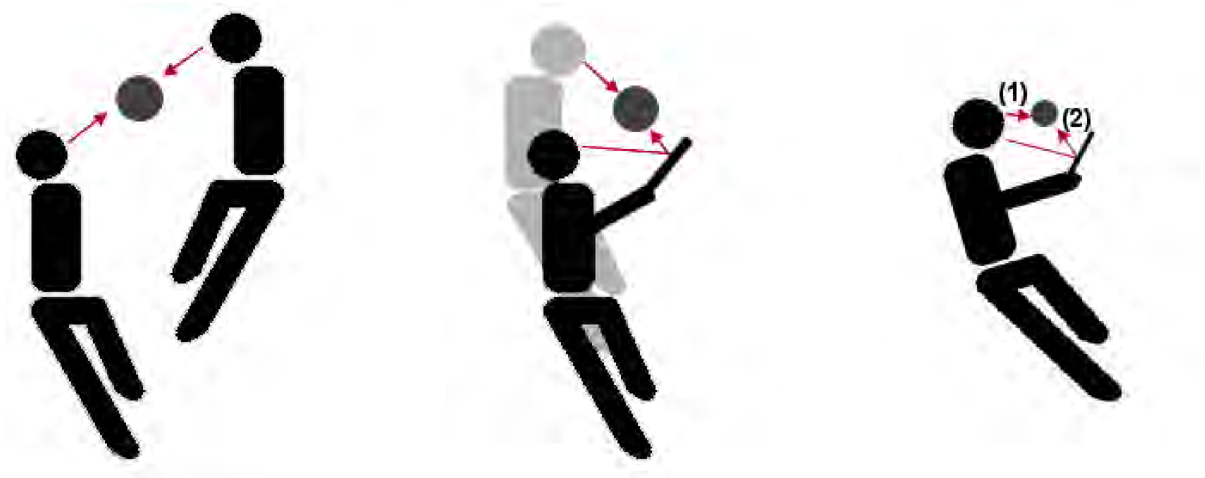


Figure 3-7: Possible viewing directions of inspectors during an inspection

Sometimes especially ski-tow operators use the method of inspecting the rope with nylon stockings only. This method is performed by wrapping the stocking around the carrying hauling rope while the rope is then pulled through the stocking. This is often performed at very high speeds. The aim of the stocking is to detect wires that stick out or to detect damage of several wires since the wires get entangled in the nylon stocking.

3.2 Situation at track ropes

At track ropes, the working situation is different during an inspection. During an inspection of carrying hauling ropes and hauling ropes the inspector is sitting or standing at a fixed workplace and the rope is moving. The inspection of track ropes has to be performed on the cabin, the carrier truck or special platforms to sit or lie on.
The various situations are shown in the following figures.
Special safety precautions have to be respected so that inspectors cannot get into dangerous situations.

Figure 3-8: Visual inspection of track ropes on a ladder, a platform, a chair and the carrier truck

Figure 3-9: Visual inspection of track ropes on a platform and the carrier truck

Figure 3-10: Visual inspection of track ropes on a special platform to sit or lie down

Figure 3-11: Visual inspection of track ropes with a special seat

3.3 Situation at standardized modular stations for monocable aerial ropeways

At standardized modular stations for monocable aerial ropeways often there is less space than, for example, at open stations of fix gripped chairlifts. At modular stations depending on the manufacturer, the inspection is often performed with the help of an additional mirror inside the station.

The mirror can be seen in Figure 3-12. The inspectors position themselves above the rope. While one inspector inspects the rope directly from above the second inspector inspects the rope from below via the mirror (compare Figure 3-13).

Figure 3-12: Mirror at a standardized modular station for monocable aerial ropeways (View from the outside)

Figure 3-13: Possible seating positions for inspectors

4 Preparation of field trials

To determine the limits of visual rope inspection two field trials were organized which were intended to reproduce the inspection circumstances of chapter 3. The results of the field trials formed the basis to determine the optimum inspection method for visual rope inspection.

4.1 First field trial

The first field trial took place at two fixed-grip chair lifts.
Table 4-1 shows more detailed technical data of the two installations. At these installations, inspections took place providing artificial damages on the rope. The preparation of the rope is described in chapter 4.3.

Table 4-1: Technical data of the two installations of the first field trial

	Installation 1	Installation 2
Rope length	938 m	1634 m
Rope construction	6x19 S	6x26 WS
Rope diameter	34 mm	36 mm
Type of installation	Chair lift, fixed-grip	Chair lift, fixed-grip
Start of operation	1992	2000

4.2 Second field trial

The second field trial focused on two issues: visual inspection at two standard modular stations for monocable aerial ropeways as well as visual inspection at track ropes.
While one rope of the two monocoable aerial ropeway installations was also prepared with artificial damages the other installation had real damages.
Visual inspection at track ropes was only discussed with a group of ropeway experts at a reversible aerial ropeway and no inspections were performed.

Table 4-2: Technical data of the two monocable aerial ropeways

	Installation 3	Installation 4
Rope length	1013 m	2945 m
Rope construction	6x36 WS	6x36 WS
Rope diameter	45 mm	47 mm
Type of installation	Chair lift, detachable	Chair lift, detachable
Start of operation	2015	2001

4.3 Artificial reproduction of damages

Since the carrying hauling ropes of the installations only had a small amount of damages or no damages at all, it was decided in advance that the ropes should be prepared with artificial damages. To prepare the artificial damages spray varnish was used.
For this purpose the damages were abstracted systematically and recreated with spray varnish or touch-up pencils.
The following damages were taken into account:

- lightning strike
- wire breaks
- corrosion
- hair lines / notches

The artificial damages were experimentally developed at the Institute of Mechanical Handling and Logistics at the University of Stuttgart to design them as realistic as possible.

4.3.1 Artificial reproduction lightning strike

If lightning strikes into ropes, usually martensite structures will develop at the points of entrance and discharge. Martensite forms, if wire material is heated up to liquid state and solidifies again very rapidly. Since martensite is a brittle material form, further operation could lead to wire breaks rapidly. Martensite appears as bluish, metallically shining discoloration on the rope (compare Figure 4-1).
Figure 4-3 shows an abstracted lightning strike.

Figure 4-1: Lightning strike bluish discoloration

Figure 4-2: Martensite with molten wires

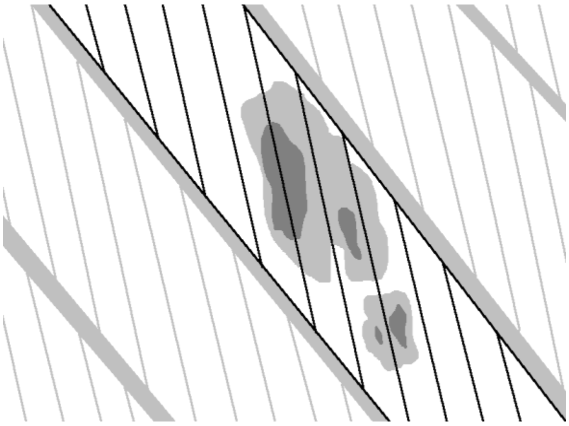


Figure 4-3: Abstraction lightning strike

To artificially recreate this type of damage both a black metallic varnish, as well as a blue varnish were chosen. To determine up to which minimum size of damage the damages get detected three different sizes of damages were applied: 0.5 x strand diameter, 1.0 x strand diameter and 1.5 x strand diameter.

Figure 4-4: Lightning strike 1.5 x strand diameter

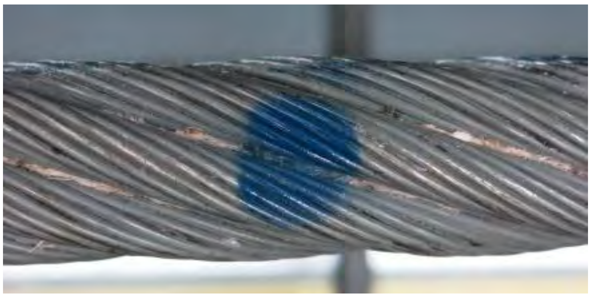


Figure 4-5: Lightning strike 1.5 x strand diameter

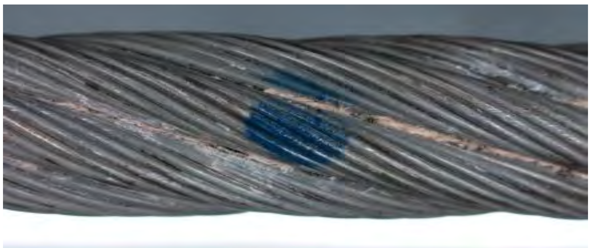


Figure 4-6: Lightning strike 1.0 x strand diameter

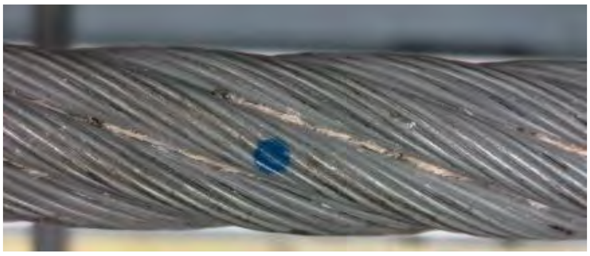


Figure 4-7: Lightning strike 0.5 x strand diameter

4.3.2 Artificial reproduction wire breaks

With wire breaks, it is necessary to distinguish between different types of damages.
There are single wire breaks (compare Figure 4-8 and Figure 4-10), several, adjacent broken wires (compare Figure 4-11) and breakage of a whole strand (compare Figure 4-12). Wire breaks appear as dark shadows at the rope surface during an inspection. Especially single wire breaks are very hard to detect.

> *Important information: It is not required to detect single wire breaks at strand ropes during a visual rope inspection.*

Figure 4-8: Single wire break

Figure 4-9: Wire break with protruding wire

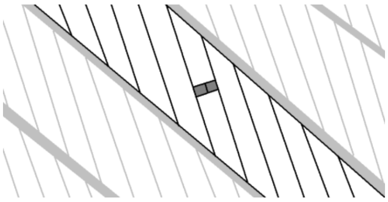


Figure 4-10: Abstraction of single wire break

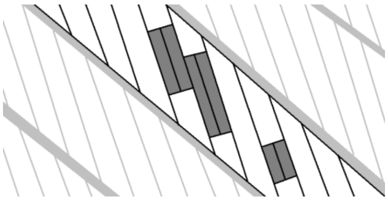


Figure 4-11: Abstraction of several broken wires

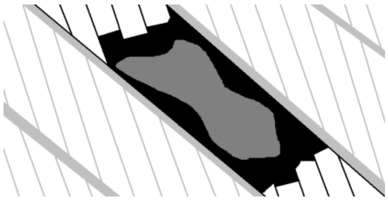


Figure 4-12: Abstraction break of whole strand

The diameters 0.5 x strand diameter, 1.0 x strand diameter, and 1.5 x strand diameter were chosen for this type of damage, too. Additionally the single wire break was artificially recreated. The artificial damages are shown in the following pictures.

Figure 4-13: Single wire break in strand touching zone

Figure 4-14: Wire break 0.5 x strand diameter

Figure 4-15: Wire break 1.0 x strand diameter

Figure 4-16: Wire break .1.5 x strand diameter

4.3.3 Artificial reproduction corrosion

If the zinc coating of ropes is harmed by damages, usually corrosion will develop as a result. Corrosion is a slow process where wires wear over time and surface loss develops, which can lead to forced ruptures. Corrosion is particularly common in strand touching zones (compare Figure 4-17).

Figure 4-17: Strand touching zone corrosion (with wire breaks)

Figure 4-18: Corrosion at fully locked coil rope

An orange varnish was chosen to create the artificial damages. To make the corrosion in the strand touching zone look as real as possible the varnish was edited with a wire brush to remove the sharp contrast between rope and varnish.
Next to strand touching zone corrosion (compare Figure 4-21) there were points with a diameter of 0.5 x strand diameter, 1.0 x strand diameter, and 1.5 x strand diameter applied on the again (compare Figure 4-22 to Figure 4-24).

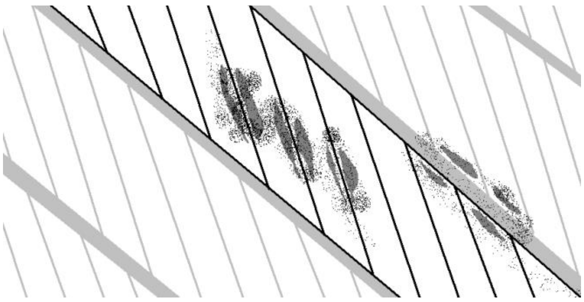


Figure 4-19: Corrosion in strand touching zone abstracted

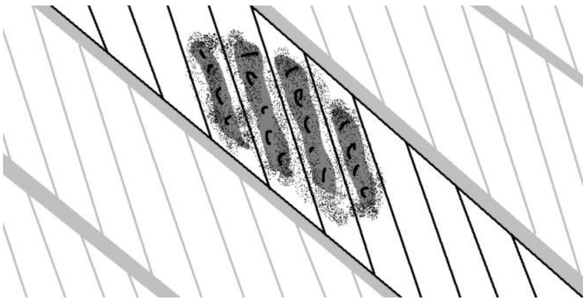


Figure 4-20: Corrosion on several strands abstracted

Figure 4-21: Corrosion in strand touching zone

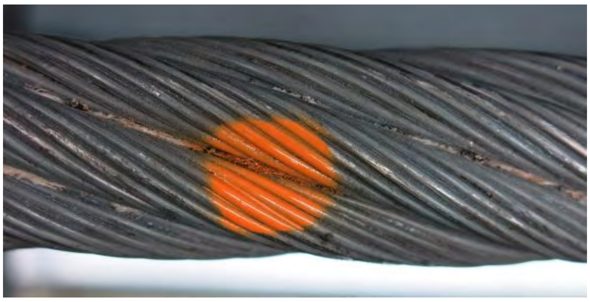


Figure 4-22: Corrosion 1.5 x strand diameter

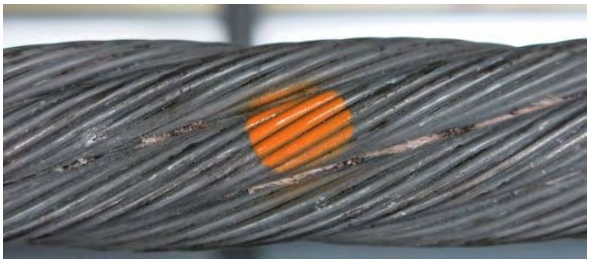


Figure 4-23: Corrosion 1.0 x strand diameter

Figure 4-24: Corrosion 0.5 x strand diameter

4.3.4 Artificial reproduction hair lines and notches

Hair lines and notches are surface damages which change the outer surface of wires, though they do not damage the rope or wire structure. Notches develop through local mechanical stress, whereas, hair lines develop through relative movement with hard bodies.
Hair lines appear on the surface as very fine friction marks over great lengths, which are partially very hard to detect and may not be found during visual inspection due to reflection of the surrounding material (compare Figure 4-26).
A notch usually occurs only locally at the point of the mechanical stress (compare Figure 4-25).
Hair lines and notches are often difficult to differentiate during visual inspection. Therefore, there was no differentiation of these two damages for the artificial reproduction and the goal was to at least detect these fine damages.

Figure 4-25: Notches on a track rope

Figure 4-26: Hair lines on a hauling rope

For artificial reproduction of hair lines and notches thin white varnish lines at the strand crown were chosen.

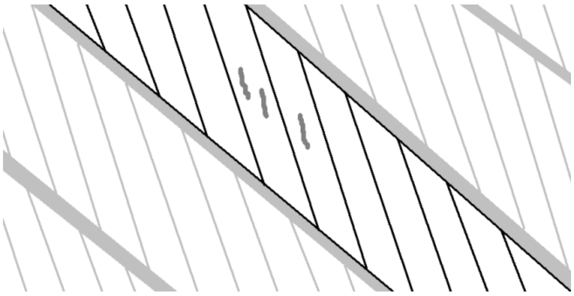


Figure 4-27: Hair lines/ notches abstracted

Figure 4-28: Artificial hair lines/ notches

4.3.5 Applying the artificial damages for the field trial

The goal while applying the artificial damages on the rope was that there is no particular order of the applied damages.

To ensure an easy recording during the field trial the points where determined in advance. The points where randomly chosen damages were applied had distances of 5 m, 10 m, 20 m, 25 m, 30 m, 40 m and 50 m.

Sometimes two or more damages were applied at the same spot to determine, if inspectors get distracted by the first damage (for example by following the damage with their eyes) and therefore overlook following damages. The different distances of 5-50 m were chosen to determine if there is a loss of concentration if no detection of damages happens for a longer period (for example for 50 m).

The damages were applied in four sections of 200 m each at the first field trial, so there were 800 m of prepared rope available for inspection at each installation. At the second field trial two sections (400 m) of rope were prepared.

4.4 Preparation of questionnaires

For future evaluation of the field trials questionnaires were created, which the participants answered before or after the inspections.
The “before-questionnaire” is discussing former experiences regarding visual rope inspection. The focus is set on the frequency and type of inspections. Additionally self-assessments are demanded where the participants should estimate what percentage of damages, introduced in chapter 4.3, they will detect during inspections. Estimations up to what minimal damage size the damages will be detected should also be given. The complete questionnaire can be found in the annex.
The “after-questionnaire” had to be answered after every inspection. In the “after-questionnaire”, among other things, the type of inspection is described (with or without breaks), the participant can describe the work place environment or if there was any loss of concentration, if tools were used (nylon stocking, mirror) and express criticism at the type of inspection.
The complete questionnaire can be found in the annex.

4.5 Selection of different types of inspections

The selection of the various types of inspections for the first field trial was made after discussions with the project team, as well as with employees of the Institute of Mechanical Handling and Logistics (IFT). At IFT, also the various types used in practice were determined.
The focus was set on speed, workplace environment, breaks and on the usage of tools. The following types of inspections were chosen:

- whole rope, without any breaks at 0.3 m/s
- whole rope, without any breaks at 0.6 m/s
- whole rope, without any breaks at 1.0 m/s
- 5 min break every 20 min at 0.3 m/s
- 5 min break every 15 min at 0.3 m/s
- 5 min break every 10 min at 0.3 m/s
- tool: nylon stocking
- tool: mirror, 5 min break every 10 min at 0.3 m/s
- inspection with 3 people at 0.3 m/s

Regarding the determined workplace environments, in conjunction with the possible installations at the first field trial, it was possible to realize the following workplace environments. At the first installation, one inspector was standing on an installed platform and the other inspector was standing on a ladder (compare Figure 4-29).
At the bottom station of the second installation, both inspectors had to stand on a ladder. It was possible to sit on a small platform, too (compare Figure 4-30).
At the top station of the second installation both inspectors could stand (or sit) on an installed platform (compare Figure 4-31).
At the second field trial, inspections were performed at a standardized modular station for monocable ropeways where a mirror was installed underneath the rope (compare chapter 3.3).
An employee of the IFT who recorded the results, boundary conditions, comments of the participants and special events during an inspection, supervised every inspection

Figure 4-29: Workplace environment at first installation

Figure 4-30: Workplace environment second installation bottom station

Figure 4-31: Workplace environment second installation top station

5 Evaluation and results of the field trials

Following the field trials, the collected data was evaluated. The evaluation starts with the "before questionnaire" which is followed by the evaluation of the damage detection rates which were achieved during the inspections. With the help of the "after-questionnaires", the usage of the tools nylon stocking and mirror is evaluated.
During the second field trial, the discussion about inspection of track ropes provides findings about safety requirements during an inspection, among other things.
With the combination of evaluation and findings a rating system will be developed which will help to rate the quality of visual inspection. The rating system will be introduced in chapter 6.

5.1 Evaluation of the questionnaire answered before inspection

> *Important information: In this chapter, all of the following evaluations are the opinions of the participants of the field trials. Some of the statements may conflict each other or the final results of the evaluation and the rating system!*

As already mentioned in the previous chapter, the participants were able to specify their previous experience, their self-assessment and their own opinion about visual rope inspection. Figure 5-1 shows the previous experience of the participants. The Figure clearly shows that the participants had a wide range of previous experience. Following the evaluation of the damage detecting rate, chapter 5.2.3 describes if there is any connection between previous experience and the damage detecting rate of a participant.
The self-assessment of the participants regarding damage detecting rate is shown in Figure 5-2. Only 22 % of the participants think that they will detect less than 50 % of all damages.

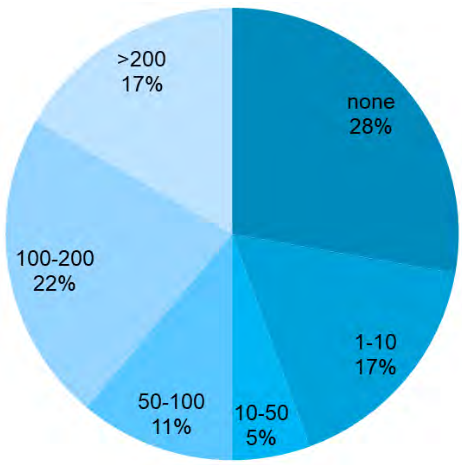


Figure 5-1: Number of previous inspections of the participants of the field trial

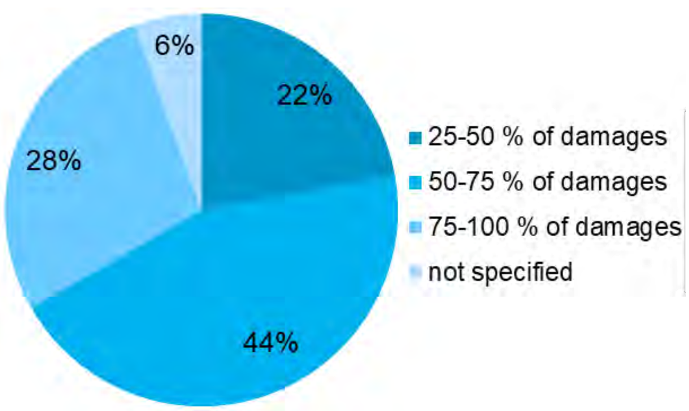


Figure 5-2: Self-assessment damage detecting rate of the participants of the field trial

The evaluation of the self-assessment regarding the minimum size of damages that will be found during an inspection can be seen in Table 5-1.
The possible options that were given in the questionnaire can be found in the annex.
As expected, most of the participants think that the smallest damages, such as wire breaks, corrosion and lightning strike with the size of 0.5 x strand diameter, as well as hair lines cannot be found. Only about a

third of the participants think that they will be able to find every size of damages.

Table 5-1: Self-assessment about minimum damage size that will be detected

Which is the minimum damage size you will detect?	Result
  All damage sizes except 0.5 x strand diameter and hair lines	39 %
All damage sizes will be detected	28 %
 All damage sizes except 0.5 x strand diameter	22 %
 All damages except hair lines	11 %

The eight most common answers to the question “Which damages are, in your opinion, important and have to be found during inspection?” are shown in Figure 5-3.
The most mentioned damages are lightning strike, corrosion, damage of several wires, wire breaks and hair lines. These statements correspond with the chosen damages, which were artificially recreated for the field trials (compare chapter 4.3).

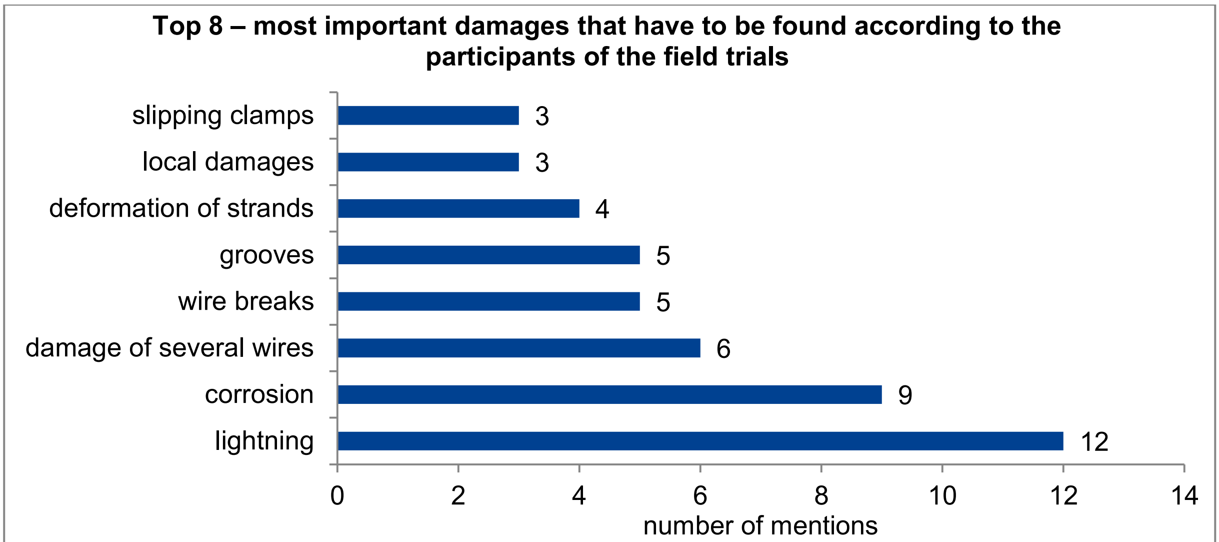


Figure 5-3: Most important damages that have to be found according the participants of the field trial

The most important attributes of an inspector during an inspection are shown in Figure 5-4. The most mentioned attributes are a high ability to concentrate and good eyesight followed by motivation and instructions.

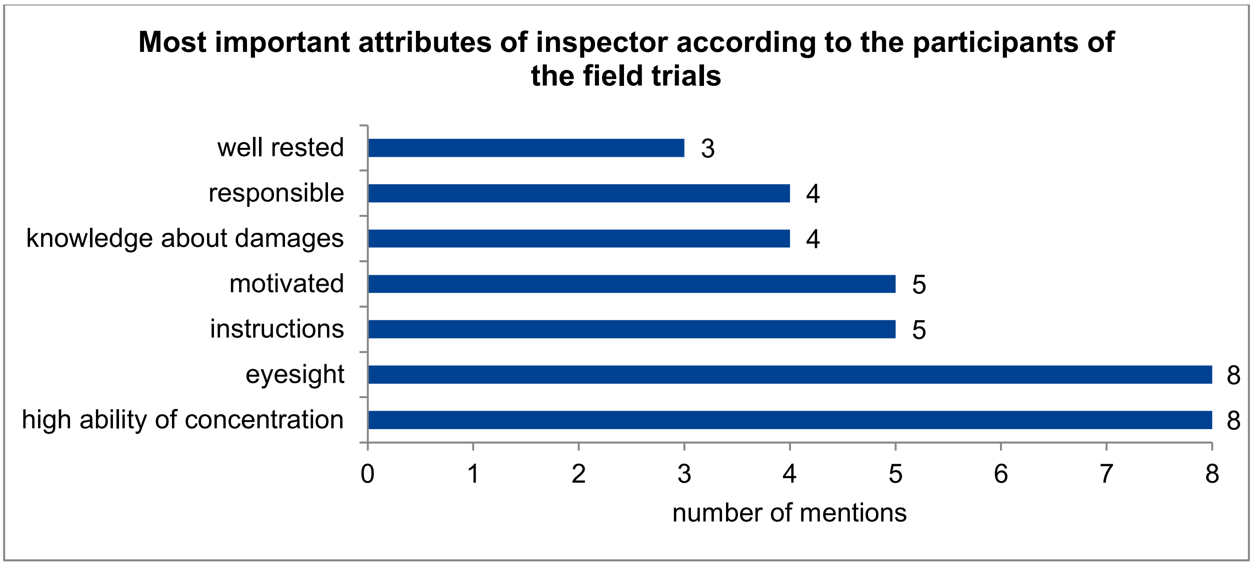


Figure 5-4: Most important attributes of an inspector according the participants of the field trial

The most important requirements to the environment and the workstation during an inspection are shown in Figure 5-5. Half of the participants state that during an inspection, one of the most important requirements is providing sufficient illumination.

The participants were asked, if they performed their past inspection during daylight or in the night and which light source they used.

Over half of the participants stated that they always do inspections during the day. Only one participant inspects ropes in the night or in the very early morning. The others have not done any before or did abstain from a statement.

Even if performing inspection during daylight, some participants use an additional light source. Especially in dark stations, where there is not enough daylight, an additional light source can be an improvement. If using an artificial source of light, it is also an advantage that there are constant light conditions at every inspection.

A comfortable sitting or lying possibility is the requirement mentioned second most. During the inspection, an uncomfortable sitting position can lead to loss of concentration and damages could be missed.

A dry rope is mentioned at the third position. If there are water drops on the rope, they can lead to reflections, which can cover damages. Furthermore, water (or ice, dirt) on the rope is an additional burden to the eyes and can decrease concentration.

If an inspection during moisture is not preventable, wiping the rope or streaming against the rope with a fan are possibilities to clean the rope.

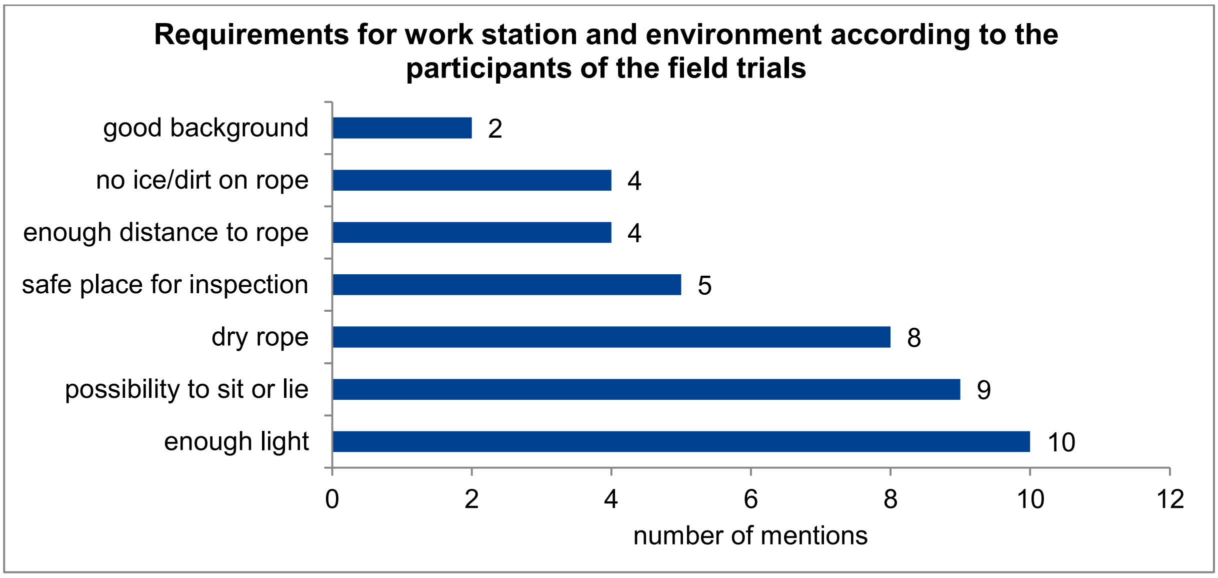


Figure 5-5: Requirements at environment and work place according the participants of the field trial

The question "what is unpleasant during an inspection regarding work station and environment" was answered by participants as shown in Figure 5-6. Most of the answers cover the reversed answers of Figure 5-5.

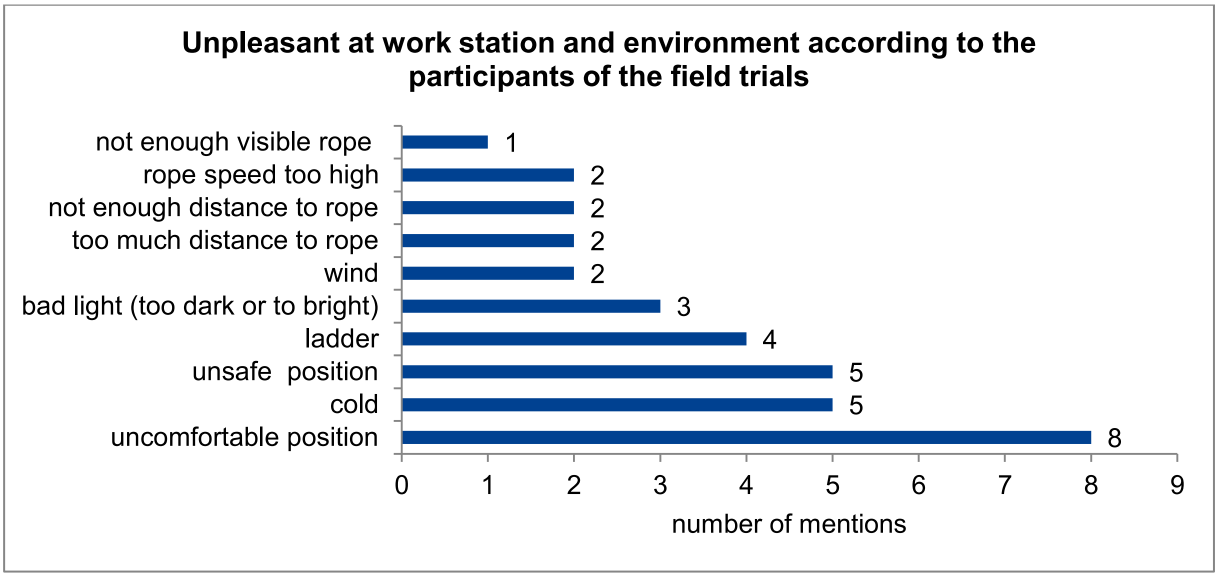


Figure 5-6: Unpleasant at work station and environment according the participants of the field trial

5.2 Determining the damage detection rate

To determine a damage detection rate, the inspection protocols, which were made by the employees of the Institute of Mechanical Handling and Logistics during the inspections, were evaluated. The damage detection rate is evaluated according to the inspection type, as well as to damage types. The damage detection rate is the result of the two (or three) inspectors in combination.

> *Important information: All of the following figures and numbers in this chapter are the results of inspections under special circumstances (artificial damages).*

5.2.1 Damage detection rate depending on type of inspection

First, the evaluation was made depending on the type of inspection. It was taken into account whether a particular damage was found or not, (while) ignoring the type of damage. The result is shown in Figure 5-7.

The best result during all inspections was achieved when inspecting the rope with three people at a speed of 0.3 m/s. The damage detection rate in this case is 79 %. This is because the third person saw damages, which were situated in the dead spot of the two other inspectors and therefore would not have been found at an inspection with only two people.

A couple of times the employees of the IFT saw damages that were in the dead spot for an inspector and therefore were not detected. Additionally, the employees of the IFT noticed that some of the damages that had a small distance to the previous damage were not detected since the inspectors discussed about the previous damage.

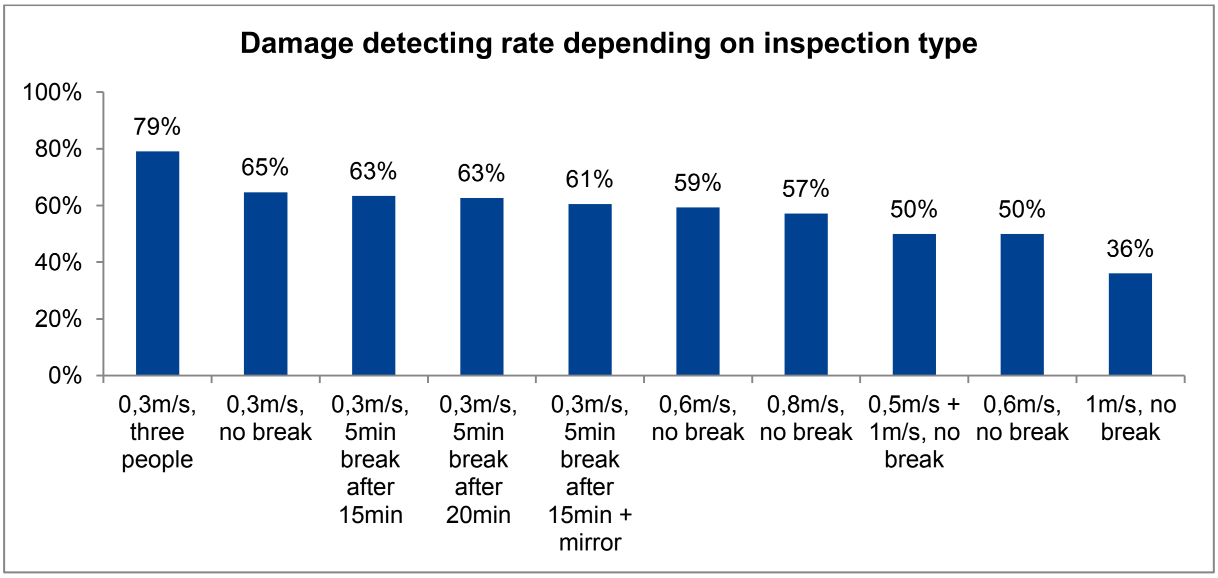


Figure 5-7: Damage detecting rate according to inspection type

It should also be noted that the inspection without any breaks at a speed of 0.3 m/s has a damage detection rate that is slightly higher than the inspections with breaks.

With a short inspection, length of only 800 m the inspection at 0.3 m/s only took about 45 minutes. Even if breaks did not have any positive effect on the ability to concentrate and thus the damage detection rate, due to observation it was clearly visible that the participants

got more restless at the end of an inspection since the sitting or lying position was beginning to get uncomfortable.
Therefore, it is not possible to state that breaks do not have any positive effect on the damage detection rate but should always be referred to the complete rope length that has to be inspected, the speed and the personal ability to concentrate.
Figure 5-7 shows that the damage detection rate at great speeds is significantly worse than at low speeds, since the ability to concentrate is decreasing quickly at high speeds. Some participants experienced dizziness at 1 m/s after a few minutes which can both decrease damage detection rate and could also be a safety hazard.
A recommendation for breaks based on the results of the field trials as well as the experience of experts is taken into account in the rating system, which is introduced in chapter 6.

5.2.2 Damage detection rate depending on type of damage

To determine the damage detection rate depending on the type of damages a classification in categories is made, representing the risk potential of the different types of damages. Damages with a high-risk potential can lead to discard criteria of the rope faster.
The risk potential of the damages in descending order can be assorted as follows

- Lightning strike
- Damage of several wires
- Hair lines
- Strand touching zone corrosion
- Single wire break
- Corrosion

Important information: The following damage detection rates include all sizes of damages during the field trials. It is not the single goal of visual rope inspection to detect very small damages.

The damage detection rate of the individual damages is shown in Figure 5-8. All inspections at all field trials were taken into account.
Whereas the damage lightning strike has the highest potential of risk, the damage detection rate is at only 64 %. The damaging of several wires also has a detection rate of only 68 %.
Both damages appear as dark shadows on the rope and are therefore hard to detect during an inspection. This is especially the case if the damage is positioned in a strand touching zone.
The damages strand touching zone corrosion and corrosion in general have a damage detection rate of about 80 % or higher. This is due to the orange-brown color of corrosion, which leads to a high contrast with the rope.

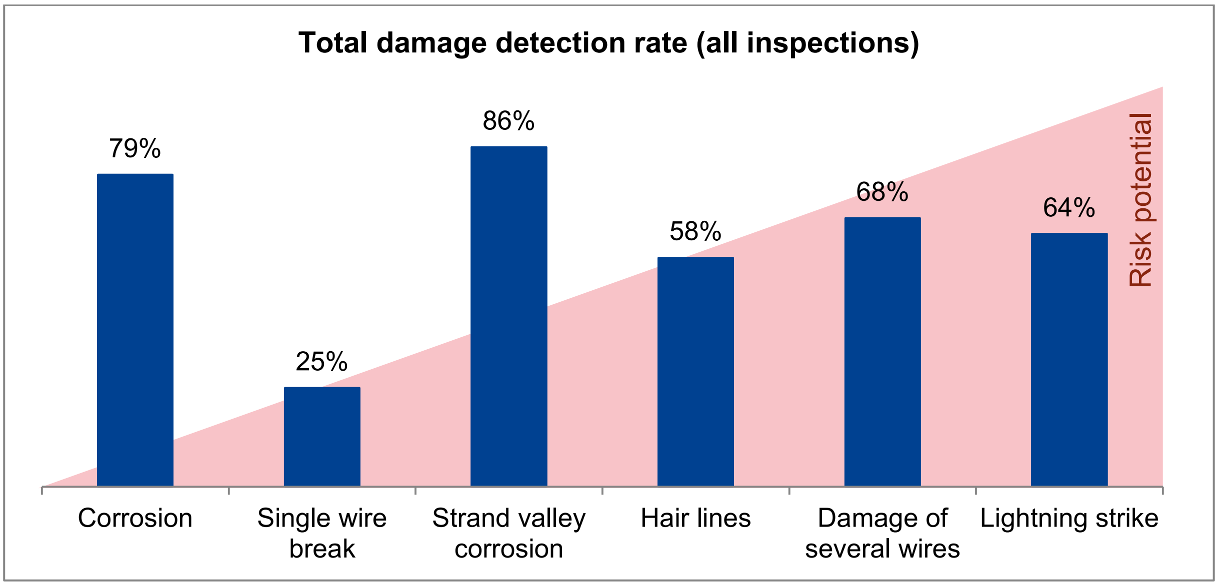


Figure 5-8: Total damage detection rate depending on damages (all inspections)

After a special event, for example a thunderstorm, an extraordinary visual rope inspection has to be performed which can be done as a type-C inspection with up to 1 m/s (compare chapter 1).

Figure 5-9 shows the damage detection rate which was reached at a speed of 1 m/s. The detection rate of the damage lightning strike decreases to 46 %. This can be explained by the typical metallic color of lightning strike, which is difficult to detect in the rope structure at high speeds.

This can also be seen with the damage of several wires, which also appears, as dark shadows on the rope. Especially with turbulent running ropes, damages can be missed.

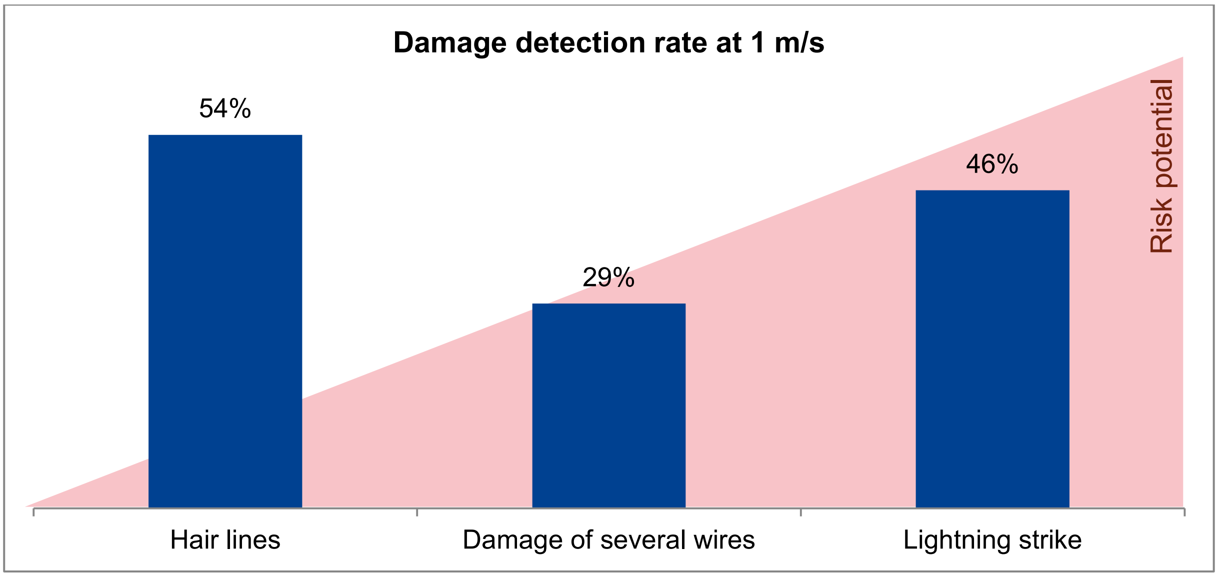


Figure 5-9: Damage detection rate at 1 m/s

As already explained, the illumination conditions are very important during an inspection. This can also be seen at the evaluation of the damage detection rate at 0.3 m/s differentiated by three stations. The evaluation can be seen in Figure 5-10.

A clear difference between the three stations of the first field trial can be seen, which can be explained by different workstations but most of all different illumination conditions.

One installation (brown) was protected from direct sunlight by a roof during inspections. At the top station of the second installation (yellow), the worst illumination conditions could be found, according to the participants of the field trial. Additionally, the drive was located at this station, which caused noise and therefore caused an additional distraction.
The combination of bad light conditions and the drive noise lead to a damage detection rate, which is considerably below the damage detection rate of the installation with a roof.
The possibilities to improve workplace and illumination conditions for visual rope inspection are introduced with the rating system in chapter 6.

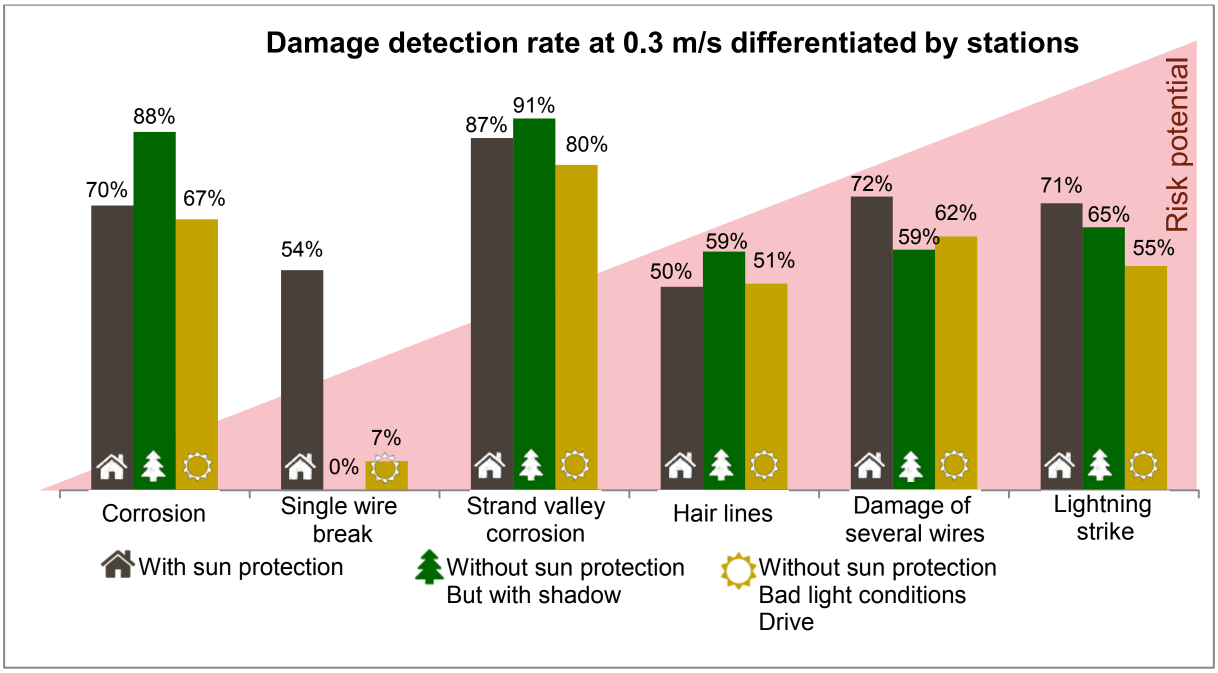


Figure 5-10: Damage detection rate at 0.3 m/s differentiated by stations

5.2.3 Connection between damage detection rate and previous experience

As shown in Figure 5-1 the previous experience of the participants was spread widely and reached from zero to over 200 previously performed visual inspections.
This chapter determines if there is any connection between previous experience of the participants and the damage detection rate and therefore more experienced participants. For this purpose, the inspection protocols were evaluated. During the inspections it was recorded who found a particular damage during the inspection. The result can be seen in Figure 5-11.
It can be seen that the previous experience does not provide an advantage regarding the damage detection rate. However, it is important that there has to be basic knowledge about the damages that could occur during visual rope inspection. It is absolutely necessary to carefully instruct new employees. The damages that have to be known by an inspector are part of the rating system, which will be introduced in the following chapter, too.
Even if the experience does not have that much of an influence on the damage detection rate it becomes apparent that the repeatability improves with increasing experience. Therefore, the scattering of the damage detection rate decreases with increasing experience.

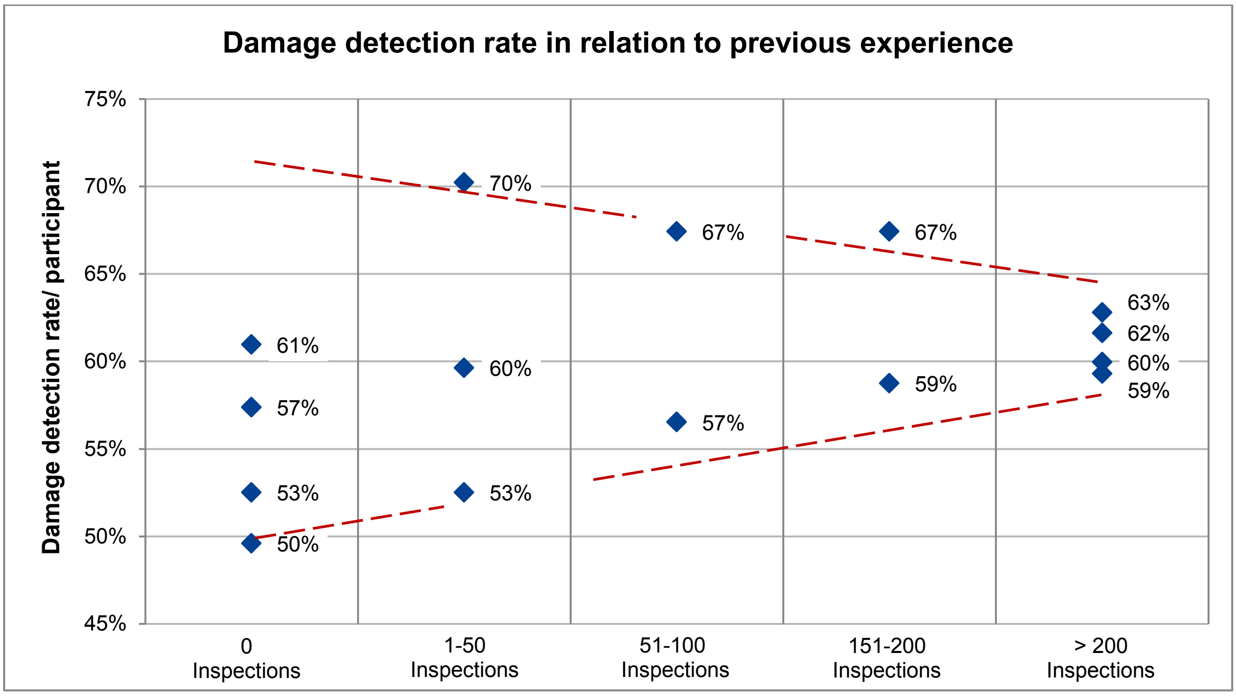


Figure 5-11: Damage detection rate in relation to previous experience

5.3 Measurement of diameter and lay length

During some of the inspections, the participants were asked to measure lay length and diameter of the rope before the inspection.
The measurement of the diameter provides information about the condition of the rope. Amongst other things, the rope diameter decreases if the rope is exposed to traction or bending. [7]
The lay length provides information about the condition of the rope, too. If the lay length severely increases over lifetime, it is possible that strands get in contact and wear increases.
The definition of the diameter can be seen in Figure 5-12.

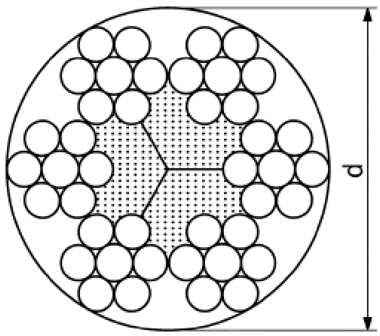


Figure 5-12: Diameter d of a round strand rope [8]

There are different possibilities for the accurate measurement of the diameter. It is very important to take the number of strands into account. If there is an even number of strands, the diameter is always measured from strand to strand. The correct measurement is shown on the right in Figure 5-13.

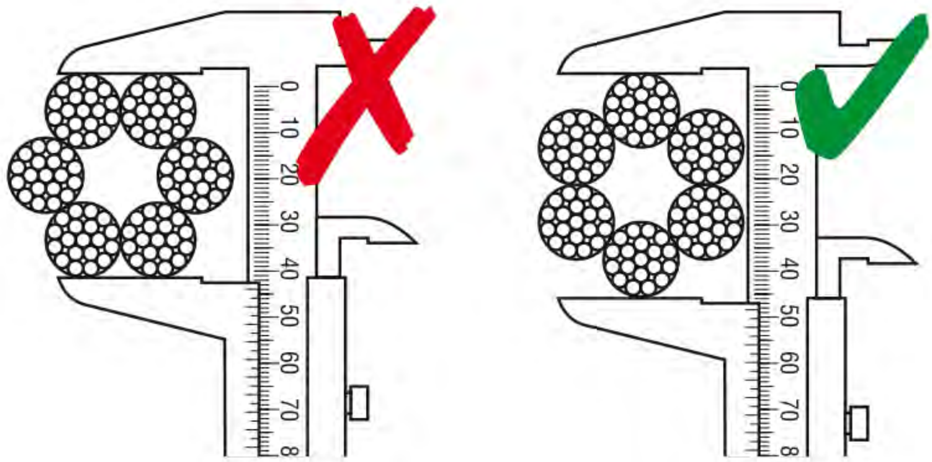


Figure 5-13: Correct measurement of the rope diameter [9]

If there is an odd number of strands, a crown is across a touching zone (compare Figure 5-14). The diameter of a rope with an odd number of strands has to be measured with a caliper that has wide jaws.

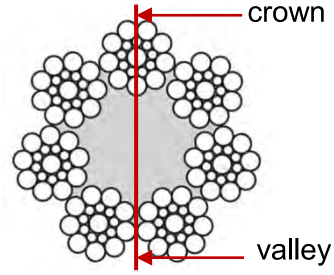


Figure 5-14: Rope cross section with an odd number of strands

The participants were asked to describe how they usually measure diameter and lay length in the "before-questionnaire". All participants measure the diameter with a caliper. Some of the participants use a caliper with wide jaws, which prevents a measurement in the strand touching zone. Half of the participants state that they measure a few times (two to three) and calculate the mean value.

The measurements of the diameter of one rope are shown in Figure 5-15.

The participants performed the measurements independently without any instructions. They could use calipers with wide jaws or they own measurement tools. The nominal diameter of the rope is 34 mm. The reference measurement was made by the IFT.

Two of the measurements were not correctly executed. The wrong measurements could be caused by a caliber that had not been reset to zero or a writing error. If this was a real measurement, this mistake would be caught since the inspector would know the real diameter and thus would measure again.

During the measurement of the diameter an accuracy in the range of one tenth of millimeter generally is sufficient.

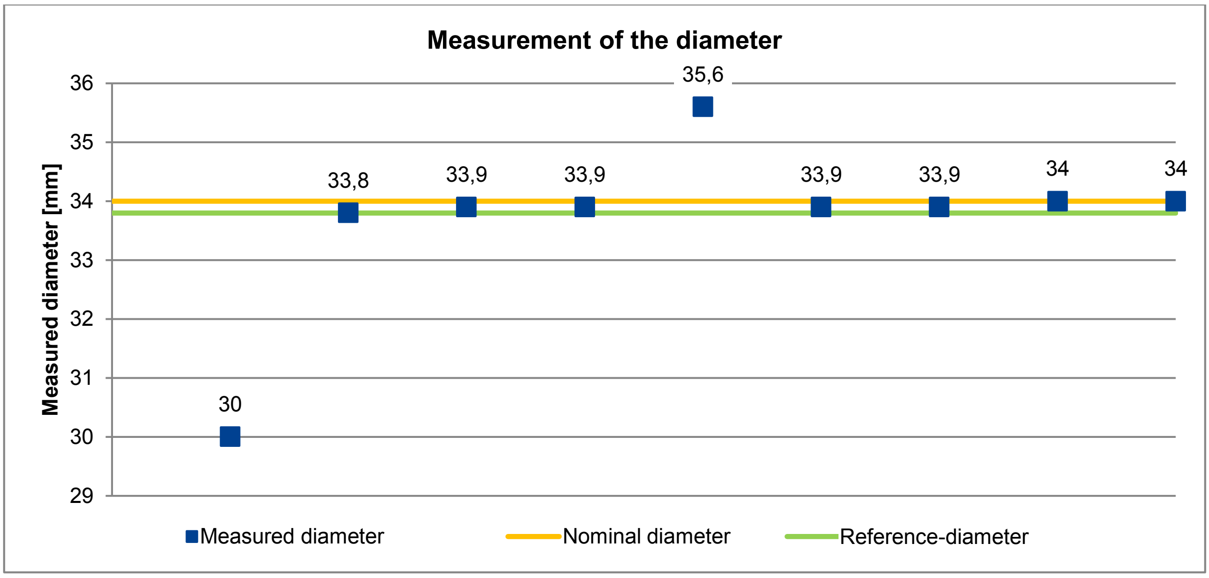


Figure 5-15: Measurement of the diameter

The lay length of the rope is defined as the pitch length (H) measured parallel to the rope axis in which either an outer wire of a spiral strand or an outer strand of a stranded rope or a leg of a cable lay rope make one complete turn (or helix) around the axis of the rope [8] (compare Figure 5-16).

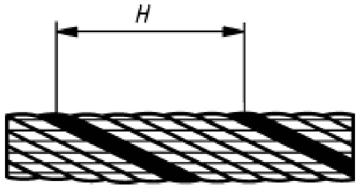


Figure 5-16: Lay length of a rope [8]

For the measurement of the lay length, most of the participants use a pocket rule. The pocket rule is positioned at one strand and a few lay lengths are counted and measured. The result will be divided by the amount of counted lay lengths. The number of lay lengths, which are counted by the participants, commonly is in between three or four lay lengths. Two participants state that they count ten lay lengths.
Another method to measure the lay length, which was not stated by any participant, is as follows. Graph paper is placed on the rope and the rope structure is transferred to the paper with a pencil lead. The lay length can be measured on the paper afterwards.
Newly invented lay length measuring devices for stranded ropes and locked coil ropes allow an easy and uncomplicated lay length measurement across the surface line of the rope. [10]
The evaluation of the lay length measurements is shown in Figure 5-17. The nominal lay length of the rope is 240 mm. In general, the participants measured correctly even if the results vary. The lay length increases or decreases during a ride which can be caused by rotation or tension differences and has not the same value over the whole length of the rope.
Also during the measurement of the lay length an accuracy in the range of one tenth of millimeter generally is sufficient.

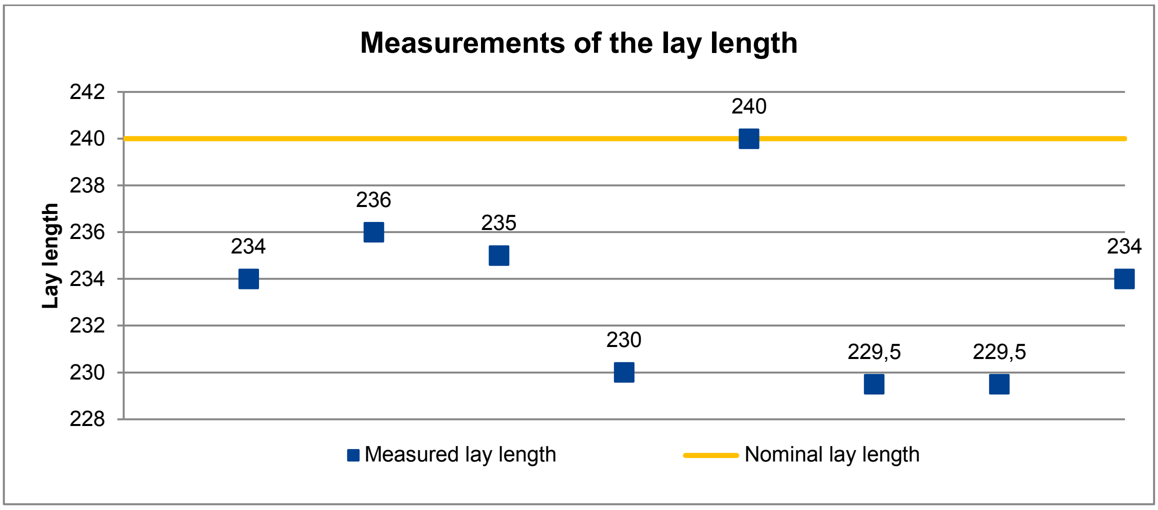


Figure 5-17: Measurements of the lay length

5.4 Inspection with nylon stocking

During the first field trial, nylon stockings were used to support some of the inspections. Nylon stockings or rags are used to detect wire breaks in the rope since the stockings could get stuck in the wire breaks (compare Figure 5-18).[11]
This method is performed at high speeds and especially by ski-tow operators.

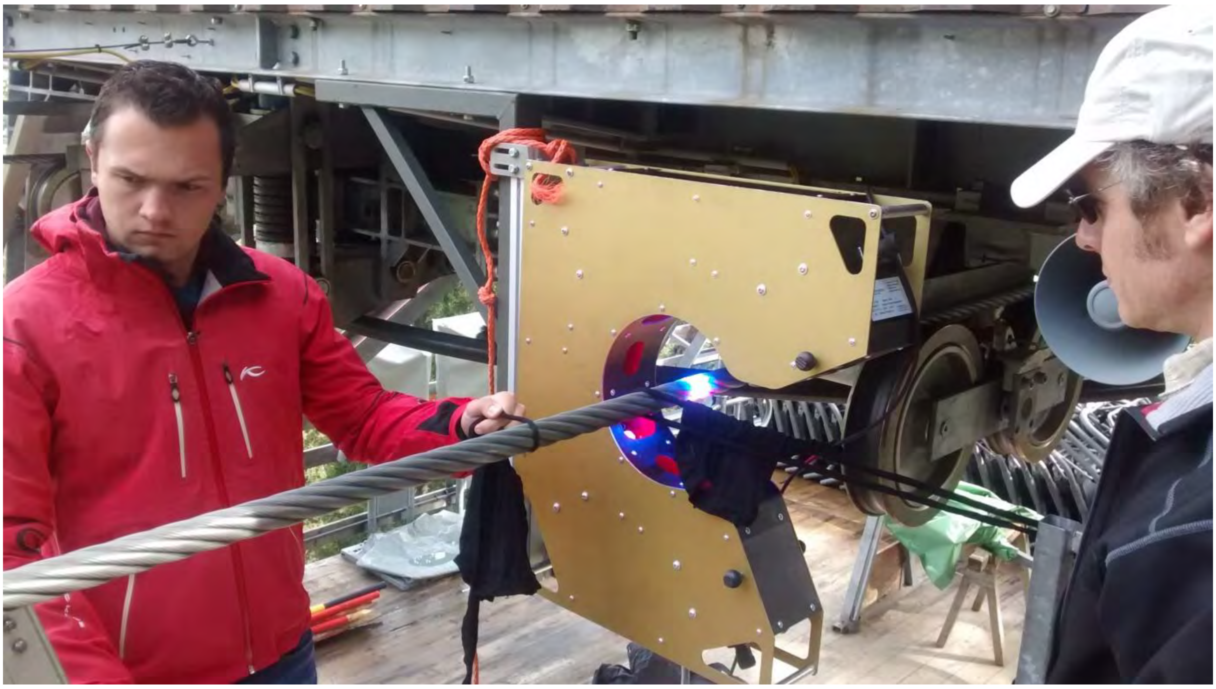


Figure 5-18: Inspection with nylon stocking

During the inspections with nylon stockings, it was not documented if and how many damages the participants did detect. Nevertheless, the participants stated their own opinion regarding inspection with nylon stockings in the “after questionnaire”.
The results are summed up subsequently.
Eleven participants in total performed an inspection with nylon stockings. Nine of the inspections were performed at a high speed of 1 m/s. The detection rate of damages, which do not have wires sticking out, is significantly decreasing (compare chapter 5.2).
This is also confirmed by the answer of the participants to the questions “which damages were especially easy to detect”. Except of damages, on which the stocking got stuck, only “bright damages” and “colored damages” are mentioned.
Some of the participants think that the stocking is disturbing during an inspection. The reasons are as followed:

- Holding the stocking is exhausting after some time
- Instable standing position on the ladder, if you have to hold the stocking
- Stocking gets stuck in smallest notches and is dragged into the roller assembly (compare Figure 5-19)
- Stocking has to be held so that the hand does not get dragged along (no wrapping around the arm)
- Damages do not get detected, if one is busy with the stocking

Figure 5-19: Nylon stocking gets stuck on the rope and is dragged into the roller battery

Nylon stockings provide quite a good possibility to detect surface damages such as wire breaks, melting after lightning strikes or hair lines. However, the inspector performing the inspection with the stocking is distracted by it and disturbed in his or her concentration.

Therefore, attention should be paid that nylon stockings are only additional tools to help with regular visual rope inspection.

Furthermore, attention has to be paid that the inspection with nylon stockings is only performed at work stations, where the inspector has a secure standing position and the minimized possibility that the stocking is getting dragged into rolls or other components.

The secure handling of nylon stockings is shown in Figure 5-20. To secure the nylon stocking at the installation is another possibility for safe handling of stockings.

Figure 5-20: Safe handling of nylon stockings

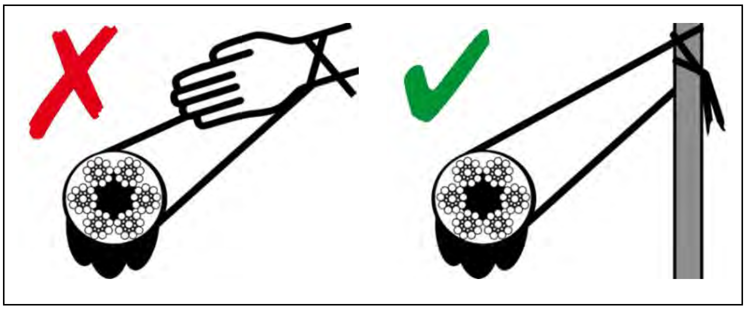


Figure 5-21: Recommended mounting of nylon stockings

5.5 Inspection with a mirror

Hand mirror

During the first field trial, some inspections were performed using a small hand mirror (compare Figure 5-22). The goal was to determine, if the mirror is helping to see more of the rope surface and therefore more damages are detected.

The damage detection rate while using the hand mirror reaches about 61 % and is therefore slightly smaller than the damage detection rate at inspections without a mirror, which reaches 63 % (comparison of inspections with a 15 min break every 5 minutes).

Therefore, the mirror does not increase the damage detection rate. The participants stated that the mirror was an additional effort, which was mostly caused by the small size of the mirror.

Additionally, the sunlight was reflected on the mirrors and distracting during inspections. It is an additional effort for the eyes and they get tired more easily. The constant holding of the mirror tires the arm and the handling gets insecure.

Caused by its size, a hand mirror is unsuitable for visual rope inspection.

Figure 5-22: Inspection with hand mirror

Mirror at standardized modular station for monocable ropeways

As already described in chapter 3.3 the second field trial focused on standardized modular stations for monocable ropeways where an additional mirror is used for inspection.

As seen in Figure 5-23 the sun was a disturbing factor at first. Due to the reflection of the sunrays, it was not possible to perform inspection through the mirror at the beginning. After applying a provisional sun protection made of cardboard (compare Figure 5-24), the inspections could be continued.

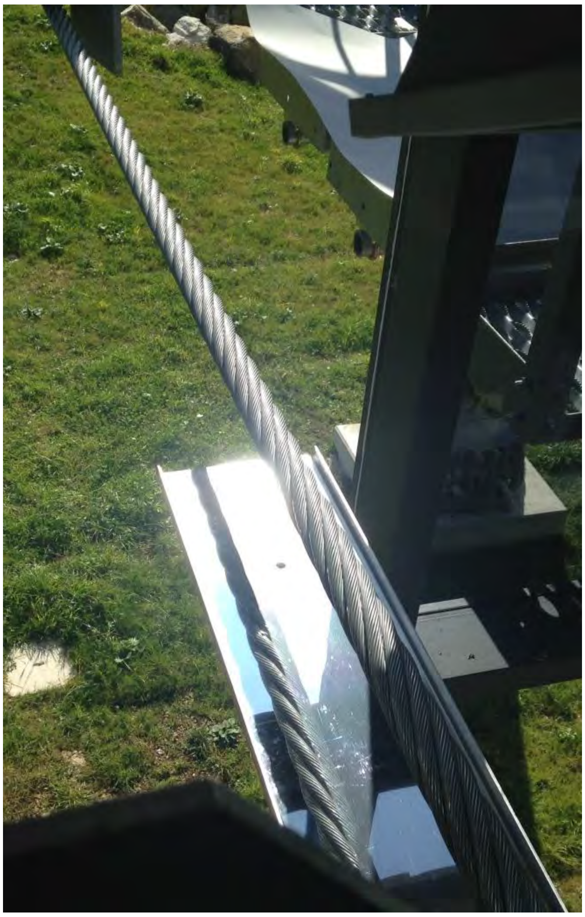


Figure 5-23: Glaring sun

Figure 5-24: Applying black cardboard as sun protection

The damage detection rate of the inspections with the mirror was at an average of 64 % and is therefore similar to the damage detection rate of inspections without a mirror at 0.3 m/s, which reached 65 %.

During the inspections, it was hard for the participants to differentiate dirt or grease from real damages that appear as shadows (e.g. wire breaks). The mirror is therefore demanding a higher concentration of the inspectors.

However, the damage detection rate clearly shows that a mirror has a comparable quality to an inspection without a mirror, if the mirror is sufficiently long (high visible rope length) and correctly used.

There was also an inspection without a mirror for comparison. At this inspection, one person was outside of the station on the first tower, while the second person was inside. During this inspection, all damages were found. However, there is not any more data so this is presumably an individual case.

Additional to the inspections at a rope with artificial damages, an inspection at a non-prepared rope was performed. The rope had real damages which can be seen in Figure 5-25.

At this inspection the whole rope with a length of about 3 km was inspected. In addition, a mirror underneath the rope was used.

Figure 5-25: Damage which could be found during the inspection

Both participants could tell their experiences during the inspection in a discussion followed by the inspection.
During the inspection, especially the noise of the drive was a disturbance for both participants. Loud noises in the background influence the ability to concentrate.
The workstation was sufficiently comfortable for both participants. The workstation can be seen in Figure 5-26. The inspection was interrupted by one break, which was used to stretch and move around a little. All damages were found during the inspection and were passed to the machine technician by radio communication. Radio was also used to stop during the inspection, if the participants wanted a closer look at certain positions.
A facility to stop would be helpful so the rope can be stopped independently and immediately.

Figure 5-26: Work station during real inspection

5.6 Influence of the background color during an inspection

During an inspection at the second field trial different background colors were tested with cardboard to determine the influence of background colors on the visibility of damages and their stress on the eyes. The colors grey, white, dark green, dark red and dark blue were tested.

- blue: pleasant, not aggressive on the eye
- white: blending, not a good background
- green: pleasant
- grey: not a good contrast to the rope
- red: possible but not pleasant over time

Therefore, dark, flat colors are most suitable as background colors. Bright colors are glaring the eye and are an additional stress for the eyes.
Artificial backgrounds offer the possibility to relax the eyes in winter, when the background is covered with snow. They can also be useful with irregular backgrounds, such as advertisements, to direct the view on the rope and increase concentration.
The rating system introduced in chapter 6 is considering the background situation and offers examples how to improve the background.

5.7 Inspection of track ropes

To discuss visual rope inspection on track ropes the project group got a demonstration of visual inspection of track ropes of two employees at a jigback aerial tramway.
During the discussion, the participants could ask questions, which were discussed and answered in the group and by the employees of the ropeway.
The installation was equipped with a platform to lie down during the inspection. This allows two people to inspect the two track ropes from above, while two people inspect the ropes from below sitting on chairs (compare Figure 5-27 and Figure 5-28)

Figure 5-27: Platform to lie down during visual inspection

Figure 5-28: Chairs on the cabin during visual inspection

The results of the discussion are collected in the following section.
Illumination conditions have a severe influence on track rope inspections, too. If the sun is glaring, almost no damages can be detected. This is especially the case, if the rope is inspected from below. The inspection from below can be prevented by using a mirror, which is installed under the track rope. If using a mirror, the rope has to be inspected from above first, followed by an inspection of the bottom of the rope through the mirror (or in reverse order).
Bad weather is also a challenge when inspecting track ropes. On the one hand, fog, snow, rain or wind can decrease visibility and on the other hand snow or rain on the rope make it hard to detect damages on the rope. Therefore, it is possible to miss damages because they are interpreted as water drops or snow.
During inspection, it may be hard or impossible to document the damages. There always has to be an additional employee (machine technician) who documents the damages.
A very important subject regarding track rope inspection is the safety of the employees. It should be ensured that there is a secure workplace during the inspection and the inspector is equipped with protective equipment. There should not be any possibility that harnesses or equipment get stuck in rolls, the towers or other parts of the cabin during the inspection.
Additionally, new employees have to be instructed carefully how to secure themselves to guarantee a safe visual rope inspection.
If all of the above mentioned tasks are conscientiously applied, there will be no danger for the safety of the employees during an inspection.

6 Recommendation to optimize the working place of visual rope inspection

The results of the field trials and their evaluation are now used to develop a rating system that allows the assessment of workstations for visual rope inspection.
The rating system allows the operator to rate every workstation that is used during a visual rope inspection type A (0.3 m/s) regarding workplace, inspection environment and inspector. The result gives an impression about the quality of the inspection.
For the rating system a criteria catalogue with factors influencing the inspection is rated with points and summarized.
The rating system can reach a maximum of 30 points. The criteria are shown in Table 6-1.

Table 6-1: Criteria catalogue for rating system

Nr.	Criteria	max. points
1	Weather protection	1
2	Sun protection / glare protection	4
3	Illumination conditions	4
4	Background	4
5	Position / posture	2
6	Switch off facility at workstation	1
7	Noise level	1
8	Distance to rope	2
9	Visible rope length	2
10	Duration of inspection until taking a break at 0,3 m/s	2
11	Rope conditions	4
12	Rope movement	2
13	Inspector	1
	Sum	**30**

The result of the evaluation has to be categorized in one of the three categories shown in Table 6-2.

Table 6-2: Categories for rating system

23-30 points Category 1	17-22 points Category 2	Less than 17 points Category 3
No improvements necessary	Improvements possible to increase rate of detected damages	Improvements recommend-ed, rate of detected damages not sufficient

If the evaluation reaches category 1, no improvement of the inspection environment is necessary. If it reaches category 2, it is possible to improve the inspection environment since conditions are not ideal and the damage detection rate will be slightly smaller than with category 1. If the evaluation reaches category 3, improvement of the inspection environment is recommended, since the expected damage detection rate is not sufficient to successfully perform visual rope inspection. Improvements should be made at criteria, which reach the lowest rating. For this purpose, the rating system offers additional information and recommendations of possible improvements for the inspection environment.
The individual criteria will be explained in detail in the following paragraphs.

1) Weather protection

0 Points	Not availble
1 Point	Available

Protection from different weather conditions, such as rain or snow, is an advantage. Especially, if the weather changes during an inspection and therefore the inspection can be continued and finished. In general, inspections should not be performed during heavy rain or snow, since raindrops or snow on the rope can influence the inspection results.

2) Sun protection / glare protection

0 Points	No protection
2 Points	Partly protected, for example trees
4 Points	Manually adjustable – depending on location of the sun or complete protection (no direct sunlight)

Protection from sun or glaring (caused e.g. by reflection on surfaces or by sunlight on a mirror) is almost indispensable during an inspection. The result of the field trials was that glaring sun, glaring backgrounds and reflections of mirrors significantly influence the damage detection rate or even make inspections impossible, since the rope structure is not visible anymore (compare Figure 6-3).
Therefore, this criterion is rated with up to four points.
The ideal sun protection can be adjusted according to solar radiation or other glaring backgrounds. These include easy tools like a sunshade (compare Figure 6-4) or cardboard that is installed at the installation during an inspection (compare Figure 6-2).

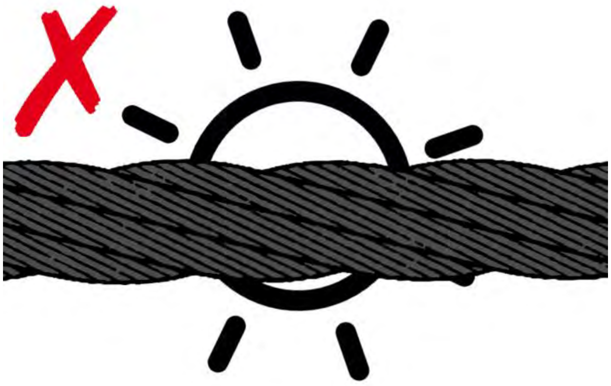


Figure 6-1: Glaring sun in the background

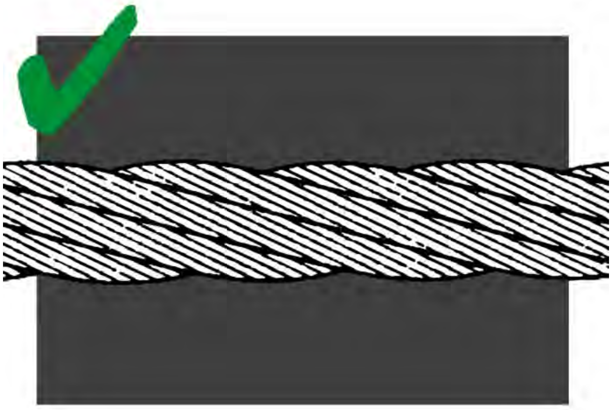


Figure 6-2: Covering of glaring sun

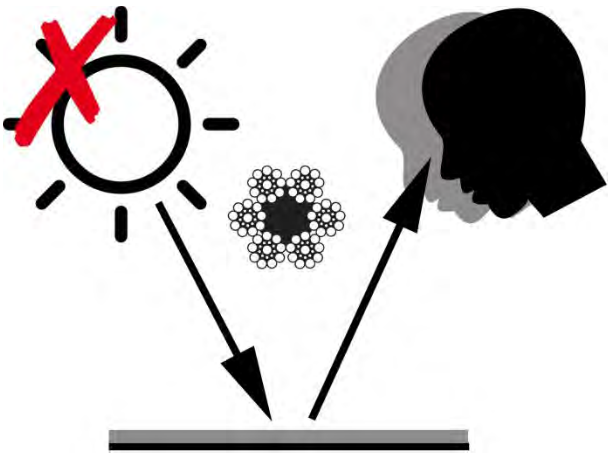


Figure 6-3: Glaring sun through mirror

Figure 6-4: Sun protection prevents glaring sun

3) Illumination conditions

0 Points	Less than 300 Lux
2 Points	300 – 500 Lux
4 Points	More than 500 Lux

Illumination is a very important criterion to perform successful visual rope inspection. If the rope is not sufficiently lighted, especially damages appearing as small and dark shadows (e.g. lightning strike) are hard to detect. Additionally, stress on the eyes increases and a higher concentration of the inspector is required.

Next to special Luxmeters there are some apps that are free of charge, which are able to determine the lux values sufficiently enough by using the smartphone camera. If an additional light source is used during inspection, it has to be ensured that the light does not glare the inspecting personnel. The stated levels are oriented at recommendations of the federal institute for occupational safety and occupational medicine (BAuA) in Germany and especially the recommendations for fine assembly work and quality assurance [12].

4) Background

0 Points	Uneven Background, reflecting background (e.g. advertisement, shining surface) or looking directly into the sky
2 Points	Even, light background
4 Points	Even, dark background

An uneven background, such as an advertisement (compare Figure 6-5), does not provide a good contrast to the rope during an inspection and therefore, the damage detection rate is decreasing. This is also the case, if the background is a reflecting surface. If looking at the rope from below, there also is not a good contrast to the rope and the eyes experience additional stress. The perfect background is even and dark and it provides a good contrast to the rope and does not stress the eyes (compare Figure 6-6). The perfect colors are dark green and dark blue, according to the result of the field trials. The perfect background can be achieved by using cardboard, which is applied behind the rope (or the mirror) for example.

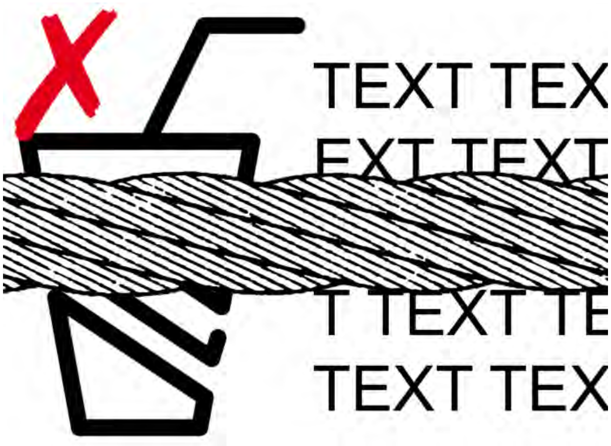


Figure 6-5: Advertisement in the background

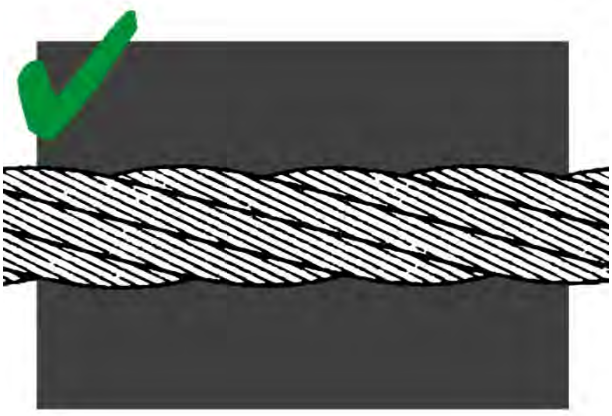


Figure 6-6: Optimum background

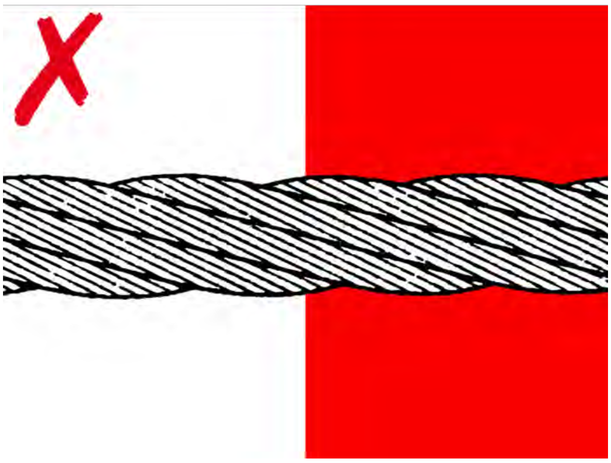


Figure 6-7: Unsuitable background colors

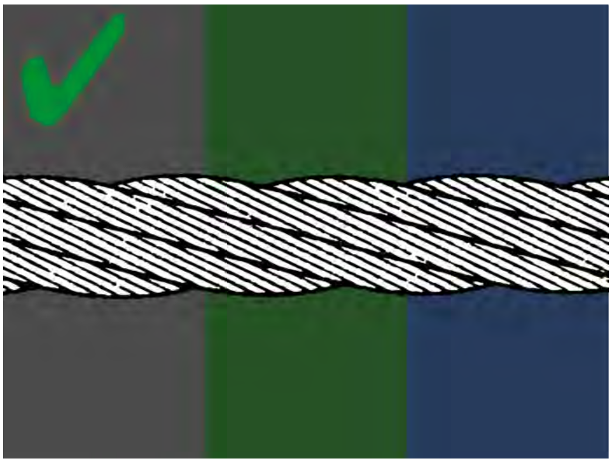


Figure 6-8: Optimum background colors

5) Position

0 Points	No possibility to sit or lie down
1 Point	Comfortable possibility to stand
2 Points	Seating possibility (Possibility to lie down at track ropes)

A comfortable possibility to sit (or lie down during track rope inspection) which allows to inspect the rope from above lead to a concentrated inspection while the inspector does not have to think about her or his own safety. Therefore, ladders have to be categorized as “no possibility”. If using ladders attention has to be paid on the secure stand of the ladder during the inspection. It is also recommended to anchor the ladder into the floor so tilting or skidding is prevented (compare Figure 6-10)

Figure 6-9: Not recommended use of a ladder

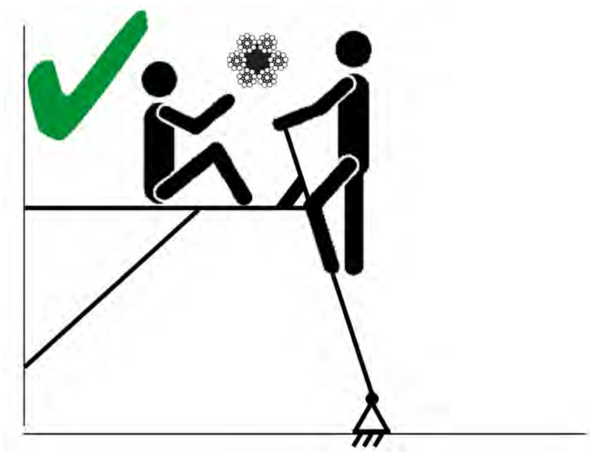


Figure 6-10: Recommended use of a ladder

6) Switch off facility at workstation

0 Points	Not available
1 Point	Available

A switch-off facility allows to stop immediately, if damages are found.

7) Noise level

0 Points	Disturbing noises
1 Point	Silence

Beyond the drive, other noise sources like an emergency diesel engine or a disturbing radio program are rated with 0 points.

8) Distance to rope

Running ropes

„thin“ rope diameter < 25 mm

0 Points	>1,2 m to max. 1,8 m
1 Point	0,7 – 1,2 m
2 Points	< 0,7 m (perfect distance)

„large“ rope diameter > 25 mm

0 Points	>1,5 m to max. 2 m
1 Point	1,0 – 1,5 m
2 Points	< 1 m (perfect distance)

Track ropes:

0 Points	>1,5 m to max. 2 m
1 Point	1,0 – 1,5 m
2 Points	< 1 m (perfect distance)

Optimum distance to the rope has to be adjusted and is depending on the rope diameter and the rope construction.
Optimum distance to the rope is achieved, if single wires are clearly visible.

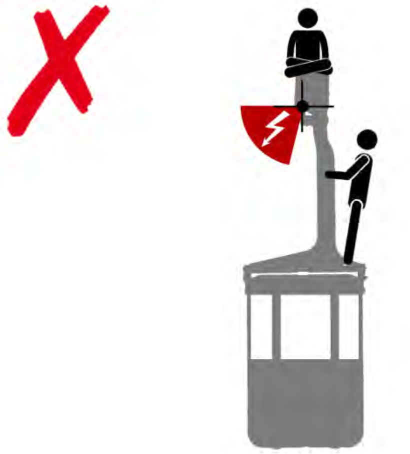


Figure 6-11: Bad position during track rope inspection. About 45 ° of the rope are not visible

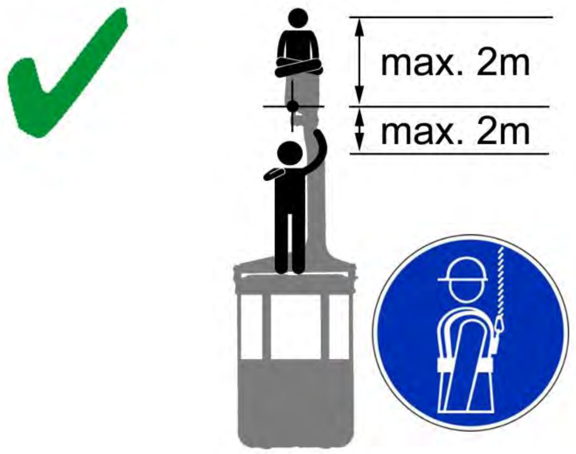


Figure 6-12: Good position during track rope inspection

9) Visible rope length

0 Points	< 1 m
1 Point	1 – 2 m
2 Points	> 2 m

A large visible rope length allows keeping track of damages with the eyes during inspection and therefore verifying damages more easily.
Seating, standing or lying possibilities have to be adjusted to get as much visible rope length as possible.
Mirror lengths less than 1 m or a visible rope length less than 1 m, caused by station design, have to be rated with 0 points.

10) Inspection duration until taking a break at 0.3 m/s

0 Points	Over 90 min without a break
1 Point	up to 90 min without a break
2 Points	up to 45 min

Based on the results of the field trial, as well as long-time experience of the project group, duration of 45 minutes until taking a break turned out as the optimum length. After 45 min first signs of fatigue may appear which can be overcome with small breaks.

11) Rope condition

0 Points	Lubrication and dirt selectively present
2 Points	Surface moderately clean
4 Points	Surface clean

The rope condition and therefore the cleaning of the rope is a very important criterion to perform successful inspections. EN 12927 specifies, “Prior to inspection wire ropes and their fixings shall be cleaned in order to be in such a state as to permit an accurate assessment of the external wire rope condition”. [13]

Selective dirt or lubrication can influence the inspection since it could cover damages. The operator has to make sure, that there is as little dirt as possible on the rope.

The following pictures show some examples of different rope conditions.

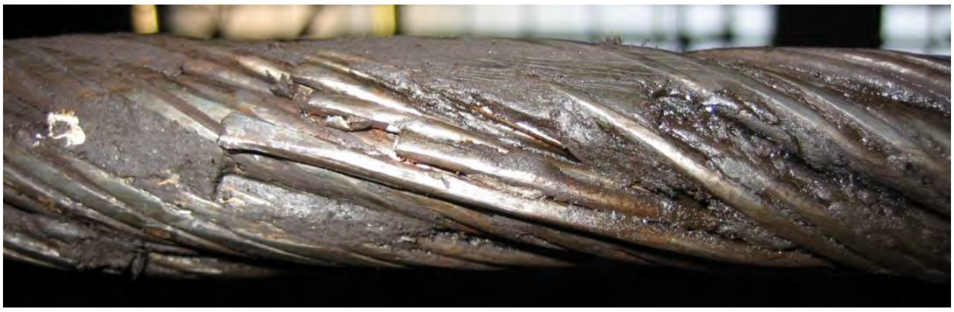


Figure 6-13: Dirty rope - inspection not possible

Figure 6-14: Dirt in strand touching zone - hard to inspect

Figure 6-15: Clean rope

12) Rope movement

0 Points	Turbulent rope movement
1 Point	Calm rope movement

Turbulent rope movement makes the rope difficult to inspect, since the concentration of the inspector decreases fast and therefore the damage detection rate decreases, too.
Therefore, the work station for inspection has to be at a place guaranteeing calm rope movement. If necessary, the speed of the rope has to be decreased (Within the criteria of the standard)

13) Inspection staff

0 Points	Instruction / knowledge about damages
1 Point	Experienced inspector

It is recommended to instruct the person who inspects the rope about the damages that have to be found during an inspection. The rating system offers example pictures for instruction. Even if an experienced inspector does not mean to get better damage detection rates (compare chapter 5.2.3), she or he will be able to assess damages and their consequences better and has knowledge about existing damages.
In the following the requirements to an inspector are listed in detail.

<u>Requirement profile of inspection staff:</u>

- A suitable inspector is a person who is physically and mentally able to perform non-destructive testing. Which includes:
    - Adequate eyesight
    - High reliability
    - Good, long-term concentration
    - Adequate fitness
    - Highly motivated
    - High safety awareness
- The inspector has to be instructed about the inspection goal
    - Recognition of outer damages (Surveillance of development of wear, corrosion and surface damages
    - Surveillance of local dimension changes
- Basic knowledge of different rope types and their special features is an advantage. The focus has to be placed on the rope used in the particular installation.
    - Rope / lay construction, core,
    - Splice (knot, tucked tail)
    - Rope end connection
- The inspector has to be equipped with all the necessary material for the inspection. Which includes:
    - Measuring equipment (caliper – optimum with wide jaws, lay length measuring equipment)
    - Marking material (Color, tape, etc.)
    - Material for documentation (inspection protocol)

- Camera
- Information about already known rope damages (from former inspection protocols or MRT reports)

- Important damages, which have to be found during an inspection, have to be known. Examples are shown on the following pages.
  (Compare rating system in the Annex)

7 Inspection protocol for visual rope inspection

Next to accurate and conscientious execution of visual rope inspection, it is important to document the inspection results. With documentation, for example, diameter changes can be detected or necessary repairs can be noted.
For this purpose an inspection protocol was developed which is an example for the documentation of an inspection at a 6-stranded rope with one splice.
The inspection protocol is separated into three sections. First of all, general information such as installation name, rope type or the participants/ station are recorded. In the second part the findings of the inspection, as well as the rope history are documented.
This includes:

- Measurement of diameter and lay length at three positions (10 m after end of splice or 10 m before cabin 1, rope middle section, 10 m before beginning of splice or 10 m before cabin 2)
- measurement of knots and tails of the splice
- Findings of visible wire breaks of loose wires in the splice
- Detected damages during inspection, including position in meters, as well as information, if the position was photographed and/or marked)

Finally, it is recorded, if repairing measures are necessary and what kind of measures have to be done. For this purpose, a deadline has to be documented.
The inspection protocol has to be signed by a responsible person (operational manager, technical manager …)
A template of the inspection protocol can be found in the annex.

8 Inspection with an optical inspection device (OID)

Authors: Stefan Messmer, Materials Technology Institute (Swiss Safety Center AG); Ropeway operators and Winspect users in an interview

For about ten years now, there are optical inspection devices (OID) existing. In some countries they are licensed as a technical support for visual rope inspection.
Next to operators, testing services providers also use these devices and their inspection experience goes up to over 100 km of inspected rope length per year. The following statements were built of experiences of both groups of users.
Insurance associations initiated the development of these devices. Since Working next to a moving rope is dangerous, it was their interest to improve the conditions for visual rope inspections and to reduce the risks during this responsible work. Now these devices allow to inspect the rope from a safe distance and the number of employees needed for the inspection is reduced. The current development of hard- and software of digital image processing allows fast recording process, which decrease the downtime of the installation, in comparison to conventional visual rope inspection. Many operators see it as an advantage that you only need a few trained and experienced employees to operate the optical inspection device and evaluate the measurements. With each evaluation, the experience of an employee increases which leads to even shorter time periods needed per evaluation.

The quality of the recordings serves the purpose of visual inspection of strand ropes and locked coil ropes. Even small damages, e.g. inclusions in wires or scratches, are visible in the recordings for the human eye. The recording does not reach the quality of high-resolution pictures of macro cameras, though. In comparison to macro cameras, the pictures cannot be enlarged anymore. Even though the quality of recordings allows considerably better visual inspections than an inspection at 0.3 m/s with the naked eye, however, it is possible that acceleration or deceleration can cause signal distortion. These positions have to be inspected manually later.

Partly automated evaluation
An image analysis software aims to identify irregularities in images with different methods and provides a list of anomalies as a result, which have to be categorized by the user most of the time. The same process happens intuitive during regular visual inspection by the inspector.

- **Wire breaks and missing wires:** Recognizability of wire breaks and missing wires depends on rope condition and the quality of the recording (illumination, sharpness and possible reflections) and is, if correctly executed, comparable with conventional visual rope inspection. Due to the all-round visibility, the detection rate can be higher than at an inspection with two pairs of eyes from only two directions.
- **Hair lines and notches, external damage:** At partly automated evaluations that have already been executed numerous damages of this kind could be found. Operators and rope inspection providers did not know about these damages.

- **Lightning strike:** Because of the rarity of this incidence (in comparison to conventional wire breaks), reliable comparative figures are not available. During day-to-day practice of a rope inspection body a few lightning strikes, that were not known before, were found.
- **Wire Distortion, disturbance in rope symmetry:** the software usually marks these damages. Quantitative statements about reliability are not possible.

Usually the software shows a variety of positions that can be deleted by the user:

- **Spots of color and grease stains:** New ropes often get a colored line during manufacturing which helps to detect changes in lay length during assembly and operation in an easy way. The automated evaluation occasionally marks color spots, which results in up to six marked positions per lay length. Similar problems may occur, if there are visible grease stains on the rope. Therefore the rope surface should be, as well as during conventional visual rope inspection, as clean as possible.
- **Glossy spots:** Galvanized ropes tend to show glossy spots in photos with extra light. Even with almost even illumination, these glossy spots are not avoidable. Usually the glossy spots are marked as abnormalities by the software.

The software provides a continuous course of diameter and lay length for the total rope length of strand ropes. Such extensive data does not exist by conventional visual rope inspection and is of great benefit for documentation and evaluation. The following events can be detected:

Lay length:

- Excessive twist stop at the end of the rope
- Twist in between cabins at insufficient lined stations (compare Figure 8-1)
- Incidents during production (e.g. stop at closing machine, compare Figure 8-2)

Diameter:

- Local wear in rope core
- Abrasion and cross section deformation, especially at winch installations
- Splice length and diameter range in splice area

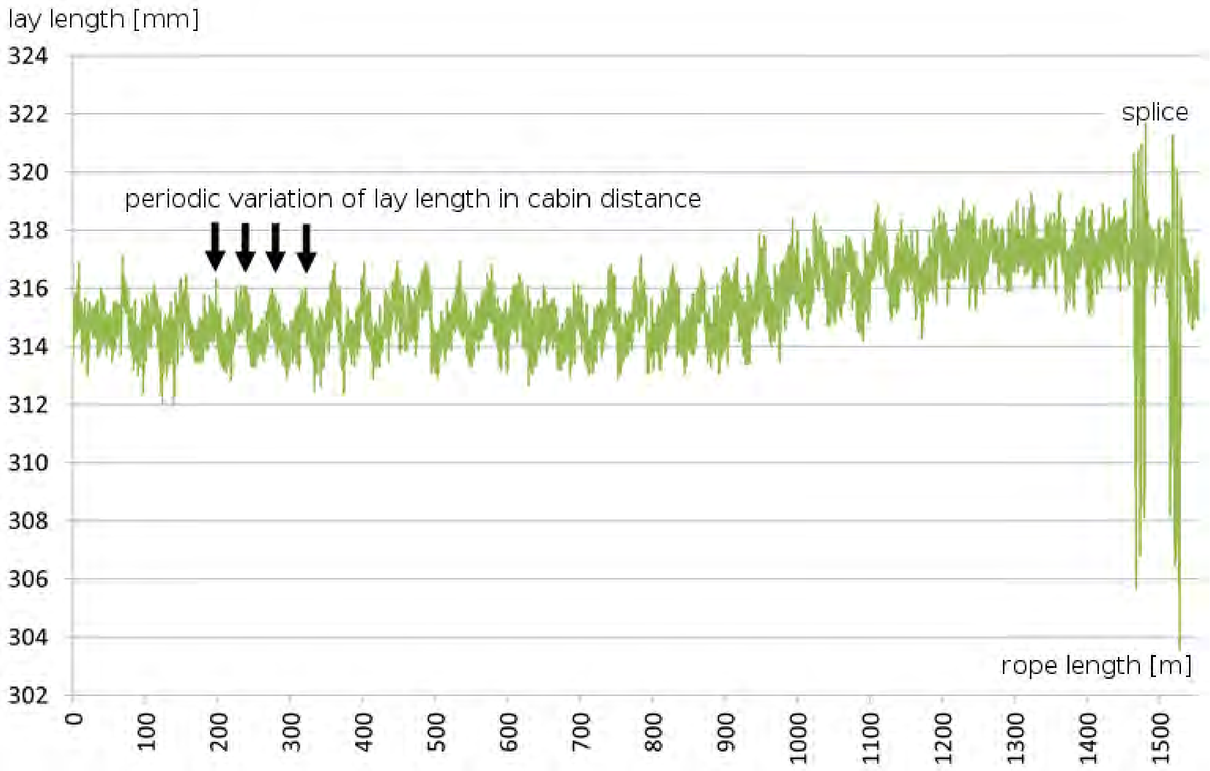


Figure 8-1:Twist at a continuously circulating detachable monocable ropeway station – the lay length shows a periodic variation in distance of the cabins

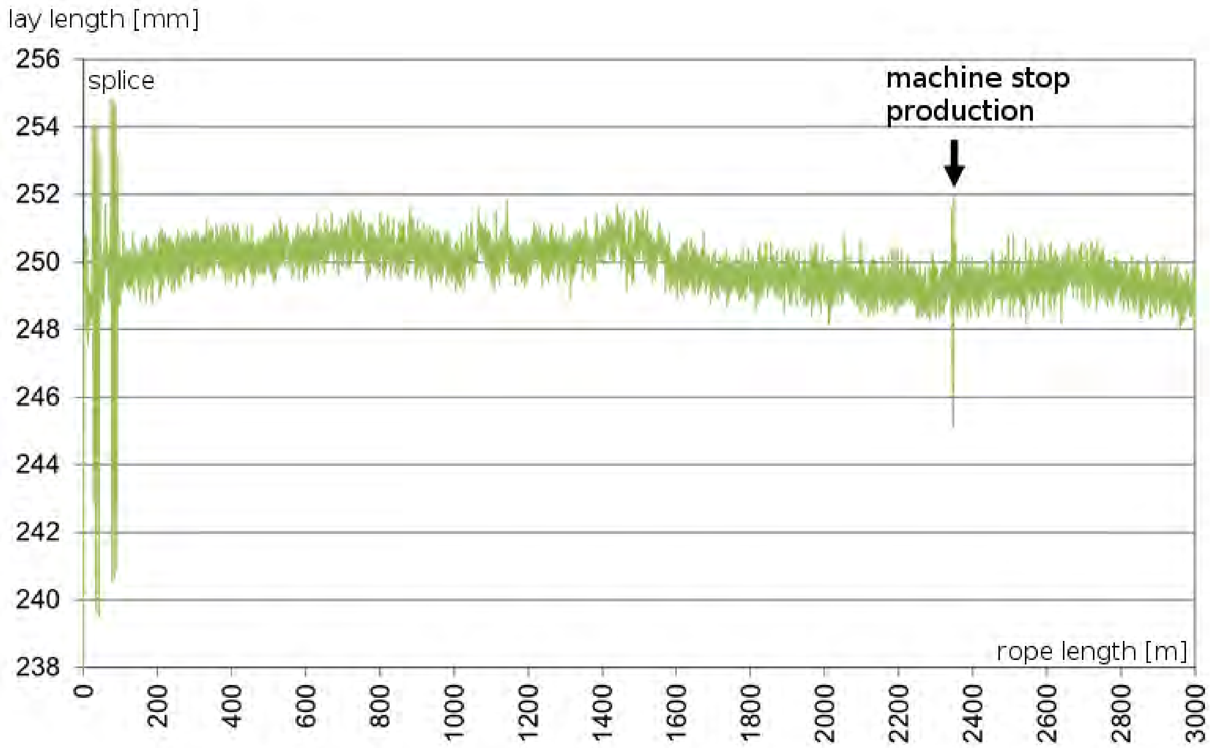


Figure 8-2: Visible machine stop during production of the rope for a continuously circulating detachable monocable ropeway

Optical inspection devices allow to prevent significant restrictions of magnetic rope testing regarding the detection of surface damages and contribute to a considerable improvement of rope testing. The devices also have the advantage that conspicuous spots are documented and measured and it is much easier to locate them.
Table 8-1 shows the disadvantages and advantages of optical inspection devices in comparison to manual visual rope inspection.

Table 8-1: Comparison of manual inspection to optical inspection devices

Disadvantage	Consistency	Advantage
• Evaluation delayed, manual follow-up inspection will only be possible later • Loss of color information due to black and white recordings • Not possible to touch the rope • Quality impressions (e.g. lubrication) may be impossible • Purchase price • Not all parts of the rope are accessible with the device (e.g. end connections or track ropes on towers) • Extraordinary inspections cannot be executed immediately due to installation time • Qualified person needed for the evaluation	• Recognizability of typical damages (wire break, lightning, distortion, hair lines, etc.) • Similar rate of detected damages • Similar physical limits of visibility (perspective, reflections, dirt / ice, …) • Dependence of inspection quality from vibrations, weather, … • For follow-up inspections it should be started at a defined point (splice) • Vibration at hauling ropes could decrease the quality of the result	• Independent from human factor • Less qualified employees necessary during the inspection • Timesaver in relation to installation availability • Documentation • Recording of diameter and lay length possible • Improved safety for employees

9 Summary

This recommendation starts with an overview over the current state of the art, which focuses on workplace conditions. These depend on the type of installation and the rope type. The necessity of visual rope inspection is described by examples which explain danger of surface damages and possible occurring consequences.

For the execution of the field trials, which determined the reliability of visual rope inspection, it was the aim to reproduce damages artificially, which commonly lead to discard criteria. The damages lightning strike, damage of several wires, hair lines, strand touching zone corrosion, corrosion and the single wire break were abstracted and the artificial reproduction was optimized by systematical tests at the IFT.

Twenty people participated in the first field trial, where different workplace conditions and different types of inspections were implemented. Inspections with and without breaks, with and without tools and with different speeds were performed at fixed-grip chairlifts. The participants could state their previous experience and their self-assessment in questionnaires during the inspections. The second field trial, which the members of the project group participated-in, focused on standardized modular stations for monocable ropeways, as well as the inspection of track ropes.

Due to the field trials, it was possible to determine damage detecting rates for the first time. The results show that, amongst other things, the speed of the rope has a big influence on the damage detection rate. At 1 m/s the damage detection rate decreases almost 30 % in comparison to the rate at 0.3 m/s.

Contrary to expectations, the experience of an inspector does not have that much of an influence at the damage detection rate. Participants with an experience of over 200 previous inspections reach the same damage detection rate as participants without any experience. However, the repeatability increases with more experience and the damage detection rate is constantly high. Additionally, an instruction is indispensable before the first inspection to guarantee basic knowledge about ropes.

Illumination conditions, as well as the background during an inspection have a big influence on the damage detection rate. If there is glaring sun or the inspector looks towards the sky, especially damages, which do not have a high contrast (e.g. lightning strike or damage of several wires), usually are not detected.

An uneven background, for example an advertisement, also does not have a high contrast to the rope and distracts the inspector during the inspection. An easy possibility to improve the search for damages is to apply cardboard behind the rope. It could be found out that especially dark colors, for example dark green, grey, or dark blue, are suitable. Bright colors, such as white or red, are not suitable.

For the inspection of track ropes, light conditions have a big influence at the possibility to detect damages, too. Caused by the special situation that the inspection has to be performed at the top of the cabin, the carriage or special seats, personal safety equipment and an instruction before the inspection are indispensable.

The inspection of ropes at standardized modular stations for monocable ropeways is supported by using a mirror, which is installed under the rope to look at the rope from below. Illumination conditions is very important when inspecting with a mirror, too. If it is considered, that there has to be enough light which does not glare the inspector over the mirror and the mirror has a sufficient length, inspecting the rope with a mirror is a sufficient alternative to perform an inspection. Especially with confined space conditions inside the station or when inspecting track ropes.

Some operators use nylon stockings to detect surface damaging of the wires. The Evaluation of the “after-questionnaire” shows that this method should only be used additional to regular visual rope inspection, since the stocking can only be used to detect damages on which it gets stuck. The stocking could be a safety hazard for inspectors and therefore, should not be held by hand or wrapped around the arm.

Next to the accurate execution of an inspection, the documentation of the results of an inspection during and after an inspection is an important part of a proper inspection. For this purpose an inspection protocol template was developed, which records the most important information of an inspection. The protocol includes general information, the measurement of diameter, lay length and splice area, rope history and found damages during an inspection, as well as necessary repair measures.

There are findings and quotas regarding the influence of factors, such as workplace condition or illumination conditions, on the result of visual rope inspection for the first time. These findings were the base for developing a rating system, which allows operators to rate their workplaces regarding several criteria and make improvements, if necessary.

The rating system is focusing on factors, such as protection from weather, illumination conditions, background, visible rope length, inspection duration or the inspection staff. It is possible to reach a maximum of 30 points and the result has to be rated in one of three categories. The categories show, if improvements of the workplace are necessary. Additionally, the rating system provides recommendations regarding the staining of the rope and the necessary basic knowledge an inspector has to have. Graphics and advice make it easier for the operator to rate and improve the workplaces.

10 Bibliography

[1] *prEN 12927 - Rev. 2016-06-17, Safety requirements for cableway installations designed to carry persons - Ropes, number 13.3.6.*

[2] e. a. S. Pernot, “Magnetic Rope Testing,” Grenoble, Apr. 2008.

[3] OITAF Work-Committee No II, *Book 3 - Survey of Magnetic Rope Testing of steel wire ropes*. Bozen: International organization for transportation by rope, 2015.

[4] Georg A. Kopanakis, “Über die visuelle Inspektion von Seilbahnseilen,” *Internationale Seilbahnrundschau.*

[5] Dr. Stefan Messmer, “Seilprüfung heute,” Wallisellen, 2008.

[6] K. Walter, *Schlussbericht über den Schaden am Tragseil "B" der Luftseilbahn Mürren-Birg.* Verfügbar unter: https://www2.sust.admin.ch/pdfs/BS/pdf/4020390.pdf (27.01.2017).

[7] Klaus Feyrer, *Drahtseile: Bemessung, Betrieb, Sicherheit,* 2. Aufl. Berlin: Springer, 2000.

[8] *DIN EN 12385-2:2003-04, Stahldrahtseile – Sicherheit – Teil 2: Begriffe, Bezeichnung und Klassifizierung.*

[9] Pfeifer Seil- und Hebetechnik GmbH, *Prospekt Seilmessmittel PFEIFER dt.* Verfügbar unter: http://www.pfeifer.de/fileadmin/user_upload/DE_doc/seiltechnik/Download/kundeninfo/Prospekt_Seilmessmittel_PFEIFER_dt.pdf (26.01.2017).

[10] “Neues Schlaglängenmessgerät für Litzen- und Spiralseile,” *Seilbahnen International Magazin*, S. 30, http://www.simagazin.com/media/files/si6_web.pdf.

[11] A. H. Peyerl, “Seilkontrolle durch Augenschein,” *Internationale Berg- und Seilbahn-Rundschau*, 1968, S. 50, 1968.

[12] Bundesanstalt für Arbeitsschutz und Arbeitsmedizin, *Technische Regeln für Arbeitsstätten - ASR 3.4 Beleuchtung.* Verfügbar unter: http://www.baua.de/de/Themen-von-A-Z/Arbeitsstaetten/ASR/pdf/ASR-A3-4.pdf?__blob=publicationFile (30.01.2017).

[13] *DIN EN 12927-7:2005-07:Safety requirements for cableway installations designed to carry persons - Ropes - Part 7: Inspection, repair and maintenance.*

Annex

Questionnaire before inspection

Participant number: __________

General questions:

Do you feel fit and well rested? Yes ☐ No ☐

Do you wear glasses? Yes ☐ No ☐ Dioptries: ________

Visual Rope Inspection:

Approximation: How many visual rope inspections have you ever done? ______________

How many inspections are you doing per year? ______________

Approximation: How many kilometers do you inspect per year? ______________

Execution visual rope inspection:

- Do you inspect at day or at night? ______________
- At night: Which kind of lights do you use? ______________
- Do you take any breaks during the inspection? ______________
- If so, how often and how long are the breaks? ______________
- How many people inspect the rope? Differentiate by rope type. (track rope, carrying-hauling rope, haul rope)

____

____

____

Measurements

Describe the measurement of the rope diameter.

Describe the measurement of the rope lay length.

What could be difficult when measuring diameter and lay length?
Discuss different methods of measurement and resulting mistakes.

Tools/Applications

Are you using any tools like nylon stockings or polishing wool? Ja ☐ Nein ☐

If yes, which tools?

What do you think about the method to exceptionally inspect with tools like nylon stockings?
(Some ski-tow operators use this method in Switzerland)
Do you think that all damages can be found with this method?

Do you use a mirror when inspecting track ropes? Yes ☐ No ☐

If yes, what kind of mirror? (Pocket mirror, rectangular long mirror, etc.)

Own assessment:

What expectations do you have of yourself?

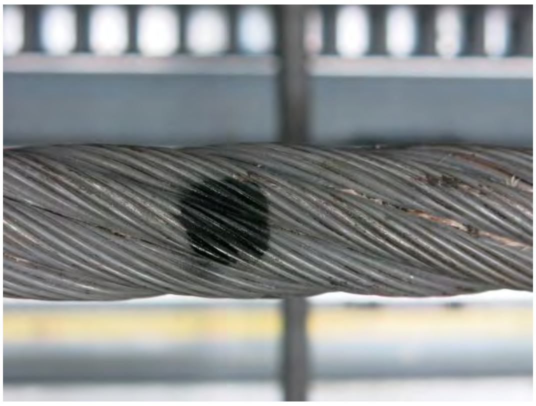
How many damages are you going to find?

75-100 % ☐ 50-75 % ☐

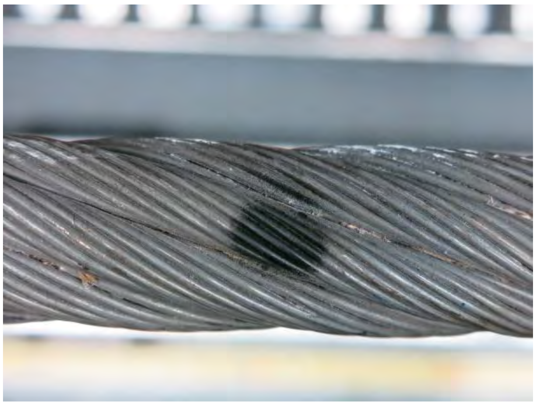
25-50 % ☐ 0-25 % ☐

Which is the minimum damage size you will detect?

corrosion in strand valley ☐



1.5 x strand diameter ☐



1 x strand diameter ☐

0.5 x strand diameter ☐

hair lines ☐

Which damages are important to your opinion and have to be found during inspection?

What are the most important characteristics of an inspector and environment to your opinion? (What do you expect of an inspector, what should the working platform and environment look like?

What do you think is especially unpleasant during an inspection? (For example working on ladders, …) Please also discuss track rope inspection.

What bothers you about the current situation of visual rope inspection?
What should be changed and/or added to regulations?

If you could decide on your own how and when you perform visual track rope inspection Type A and C, how would you execute the inspection? (Please differentiate between different rope types)

Did you experience any positive or negative events during past inspections?
For example not detecting big damages or almost invisible damages found.
Would you anonymously describe the event (type of installation, rope type, etc.)?

Questionnaire after inspection

Participant Number: ________

Station

At which station did the inspection take place? Hexenkessel top ☐ Längenfelder ☐ Hexenkessel valley ☐

Lay length: ____________ Diameter: ________________

Describe the condition of the rope (Age, lubrication, …)

____

____

____

Inspection

Did you inspect the whole rope without breaks? Yes ☐ No ☐

Did you find damages? Yes ☐ No ☐

How often did you ask to stop the rope? ________________

Which damages were especially **easy** to find?

____

____

Which damages were especially **hard** to find? ________________

____

____

Did you have problems in concentrating? Yes ☐ No ☐

If yes, when did they come up (approximately)? ____________________

Have you been distracted? Yes ☐ No ☐

If yes, what did distract you? ____________________

____

____

____

Did you talk to your inspection partner? If yes, how often? all the time ☐ often ☐ almost never ☐ never ☐

How often did you look away from the rope to recover your eyes?
every minute ☐ every 1-5 min. ☐ less than every 5 min. ☐ unaware ☐

Do you have any other tricks to recover your eyes or to increase concentration?

____

____

____

Inspection with breaks

How many breaks did you take? ____________________

How long did they last? ____________________

Do you think the breaks were helpful, have you been more concentrated afterwards? Yes ☐ No ☐

Environment and work platform

Was your work platform comfortable? Yes ☐ No ☐

If not, what could have been better? ______________________________

____

____

____

____

Describe your position in front of the rope:

- Sitting or standing?
- Looking from above or from underneath the rope?
- Distance to rope?

____

____

____

____

Did you have enough light? Yes ☐ No ☐

Were there any environmental influences? Yes ☐ No ☐
(For expample by bright sunlight)

If yes, which influences? ______________________________

____

____

Did you use any tools? (Nylon stockings, …) Yes ☐ No ☐

If yes, which tools? ______________________________

Do you think the tools were helpful? Please explain your answer.

____

Critisicm – positive/negative about this type of inspection

Location:		Date:	
Installation:			
Rope:			
Inspector/Station:			
Weather:		Temperature:	°C

Rope data [mm]			
nominal-∅:		**Nominal lay length:**	
	Position 1[1]	**Position 2**[2]	**Position 3**[3]
$\varnothing_{max}$			
$\varnothing_{min}$			
∅			
lay length:			

Splice	**T1**	**K1**	**T1'2**	**K2**	**T2'3**	**K3**	**T3'4**	**K4**	**T4'5**	**K5**	**T5'6**	**K6**	**T6'**
$\varnothing_{max}$[mm]													
$\varnothing_{min}$[mm]													
Visible wire breaks													
Loose wires													
Notes													

Notes / rope history:	
Repairs of rope (What, When?)	
Other	

Results of inspection: **(Found damages with position, was damage marked/photographed?,…)**	**Reference- / Start point:**	

Maintenance-/Repair measures necessary (please check)

☐	**Measures necessary (write down with deadline)**	☐	**No measures necessary**

Name, first name of person responsible:	
Date, Sign of person responsible:	

TYPE A	**Rating of inspection environment Visual Rope Inspection**

Location:		Date:	
Installation:			
Rope:		Inspection station:	
Rated by:			

Criteria					**Achieved points**
Weather protection					
1	0	Not available			
	1	Available			
Sun protection / glare protection					
4	0	No protection			
	2	Partly protected, trees for example			
	4	Manually adjustable – depending on location of the sun <u>or</u> complete protection (no direct sunlight)			
Illumination conditions					
4	0	less than 300 lux			
	2	300 – 500 lux			
	4	more than 500 lux			
Background					
4	0	Uneven Background, reflecting background (e.g. advertisement, shining surface) or looking directly into the sky			
	2	Even, light background			
	4	Even, dark background			
Position					
2	0	No possibility to sit or lie down			
	1	Comfortable possibility to stand			
	2	Seating possibility (Possibility to lie down at track ropes)			
Switch off facility at inspection station					
1	0	Not available			
	1	Available			
Noise level					
1	0	Disturbing noises			
	1	Silence			
Distance to rope					
2		Running ropes		Track ropes	
		Rope Ø > 25 mm	Rope Ø < 25 mm		
	0	> 1.5 m - max. 2 m	> 1.2 m - max. 1.8 m	> 1.2 m	
	1	1.0 – 1.5 m	0.7 – 1.2 m	0.7 – 1.2 m	
	2	< 1 m (optimum)	< 0.7 m (optimum)	< 0.7 m (optimum)	
Visible rope length					
2	0	< 1 m			
	1	1 – 2 m			
	2	> 2 m			
Inspection duration until taking a break at 0.3 m/s					
2	0	Over 90 min without a break			
	1	Up to 90 min without a break			
	2	Up to 45 min			
Rope condition					
4	0	Lubrication and dirt selectively present			
	2	Surface moderately clean			
	4	Surface clean			
Rope movement					
2	0	Turbulent rope movement			
	2	Calm rope movement			
Inspection staff					
1	0	Instructions / Knowledge about damages			
	1	Experienced inspector			
				Sum	***/30***

Important information for the use of this rating system for visual rope inspection

The rating has to be performed separately for each inspection station!
(Therefore for each inspector and her or his inspection station)!

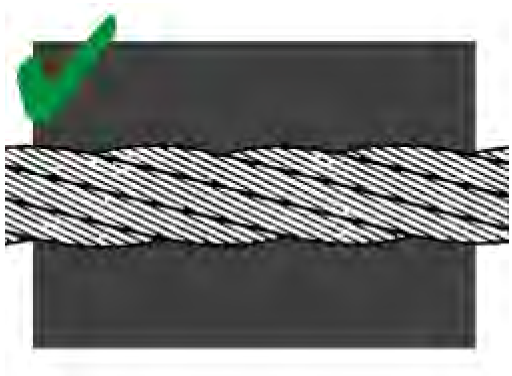
Results of the rating have to be categorized into one of the following categories.

23-30 points Category 1	17-23 points Category 2	less than 17 points Category 3
No improvements necessary	Improvements possible to achieve a better damage detection rate	Improvements recommend-ed Damage detection rate is not sufficient

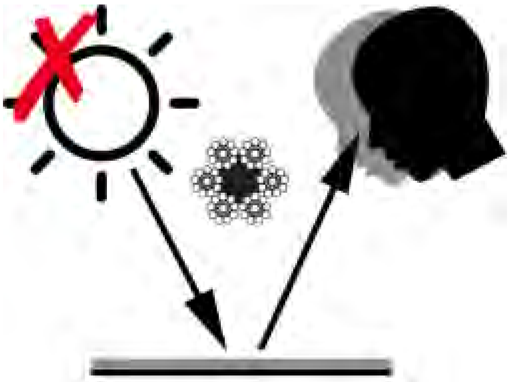
Sun protection / glare protection

If the inspection station is only partly protected from the sun, the protection is depending on the time of day when the inspection is taking place.

Picture 1: Glaring sun in the background – not a good contrast to the rope



Picture 2: Sun protection covers the sun – very good visibility of the rope



Picture 3: Sun is reflecting via the mirror

Picture 4: Sun protection prevents reflection

TYPE A

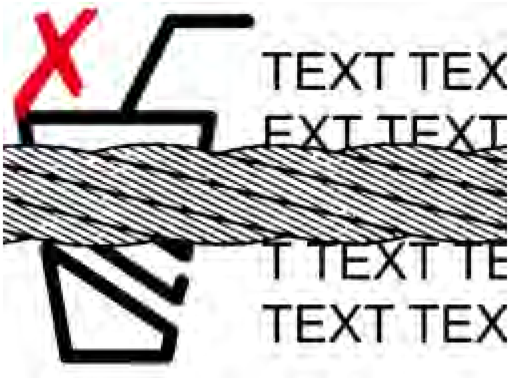
Rating of inspection environment
Visual Rope Inspection

Illumination conditions:

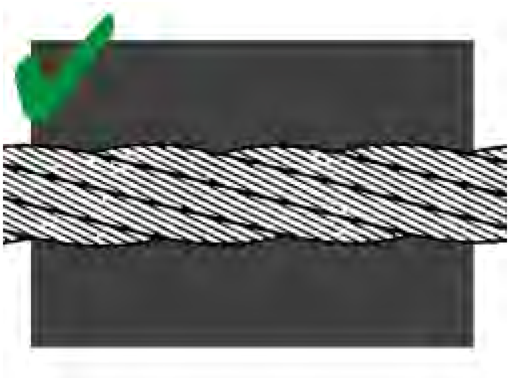
- Daylight is rated as over 500 lux
- Artificial light sources have to be positioned that the employees are not glared
- Illumination has to be consistent during an inspection. (Not consistent illumination is caused by clouds for example)

Background

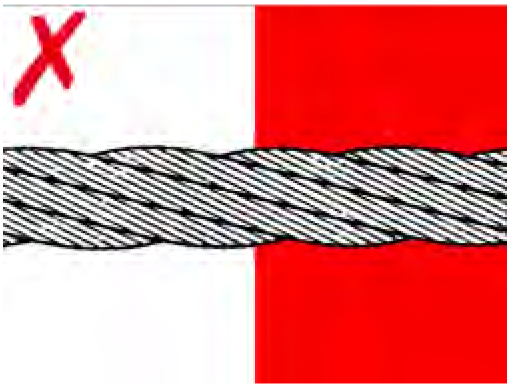
Uneven and glaring backgrounds disturb the ability to concentrate.



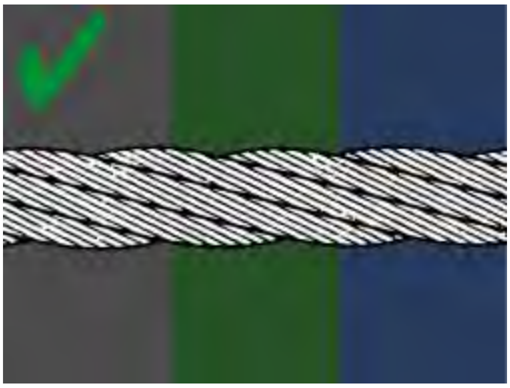
Picture 5: Advertisement in the background



Picture 6: Optimum background



Picture 7: Not suitable background colors

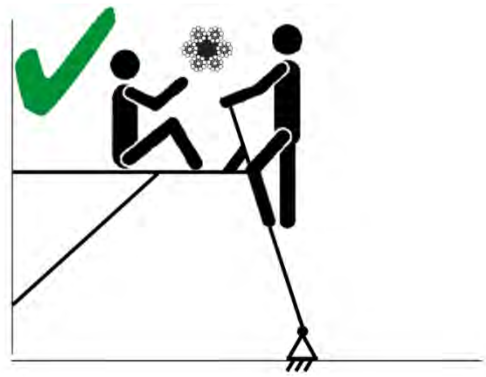


Picture 8: Optimum background colors

Seating possibility:

Ladders have to be rated with 0 points.

Picture 9: Not recommended usage of ladders



Picture 10: Recommended usage of ladders

<u>Switch-off possibility</u>

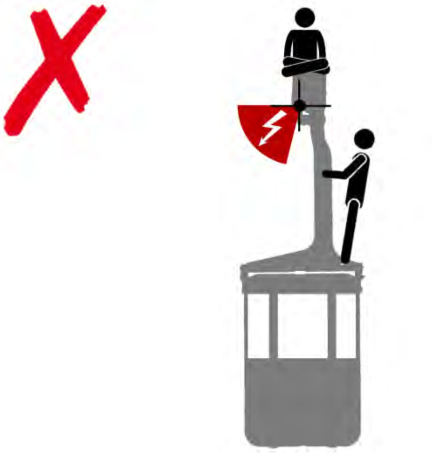
A switch-off possibility makes it possible to stop immediately if damages are found.

<u>Noise level:</u>

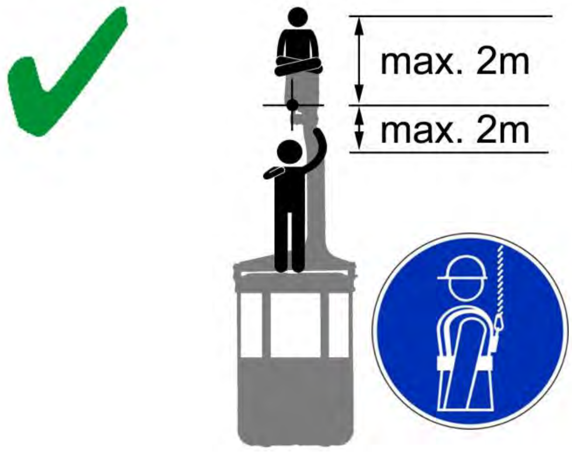
Other than the drive other noise sources like an emergency diesel engine or a disturbing radio program are rated with 0 points.

<u>Distance to rope:</u>

Seating or standing possibilities have to be adjusted to get optimum distance to the rope if possible. Optimum distance to the rope is achieved if single wires in the outer strands are clearly visible.



Picture 11: Bad position during track rope inspection. About 45 ° of the rope aren't visible



Picture 12: Good position during track rope inspection

<u>Visible rope length:</u>

- Seating / standing or lying possibilities have to be adjusted to get as much visible rope length as possible.
- Mirror length less than 1 m or a visible rope length less than 1 m, caused by station design, have to be rated with 0 points.

<u>Rope condition:</u>

- The rope has to be sufficiently clean to guarantee a successful inspection. It is not possible to inspect a rope that is coated with lubrication and dirt!
- The following pictures show examples of different rope conditions.

Picture 13: Very dirty rope – inspection not possible!

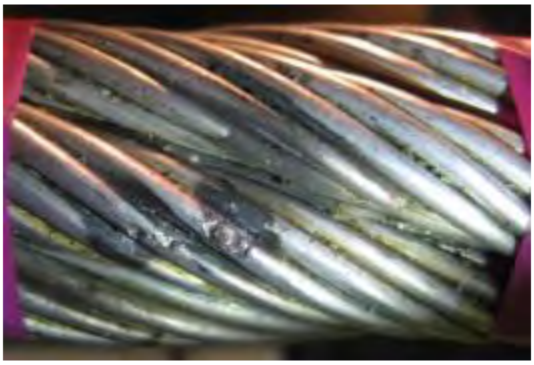
Picture 14: Dirt in strand touching zones – hard to inspect

Picture 15: Clean rope

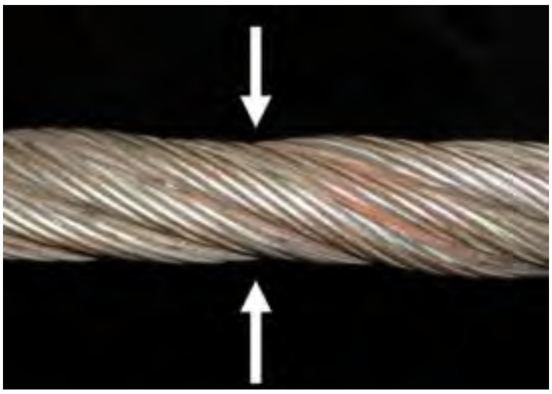
Requirement profile of inspection staff:

- A suitable inspector is a person who is physically and mentally able to perform nondestructive testing. Which includes:
  - Adequate eyesight
  - High reliability
  - Good, long-term concentration
  - Adequate fitness
  - Highly motivated
  - High safety awareness
- The inspector has to be instructed about the inspection goal
  - Recognition of outer damages (Surveillance of development of wear, corrosion and surface damages
  - Surveillance of local dimension changes
- Basic knowledge of different rope types and their special features is an advantage. The focus has to be placed on the rope used in the particular installation.
  - Rope / lay construction, core,
  - Splice (knot, tucked tail)
  - Rope end connection
- The inspector has to be equipped with all the necessary material for the inspection. Which includes:
  - Measuring equipment (caliper – optimum with wide jaws, lay length measuring equipment)
  - Marking material (Color, tape, etc.)
  - Material for documentation (inspection protocol)
  - Camera
  - Information about already known rope damages (from former inspection protocols or MRT reports)
- Important damages which have to be found during an inspection have to be known.
  Examples are shown on the following pages.

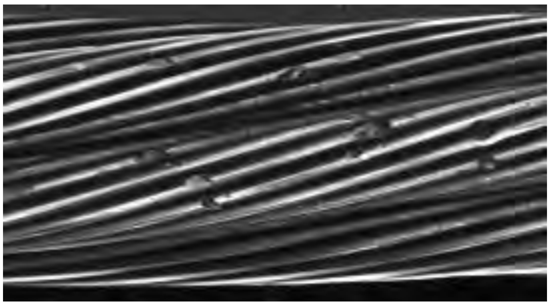
Examples rope damages on strand ropes

Lightning strike / Current flow	
	
	
	
	

Corrosion



Hair lines / notches



TYPE A	Rating of inspection environment Visual Rope Inspection	Strand ropes

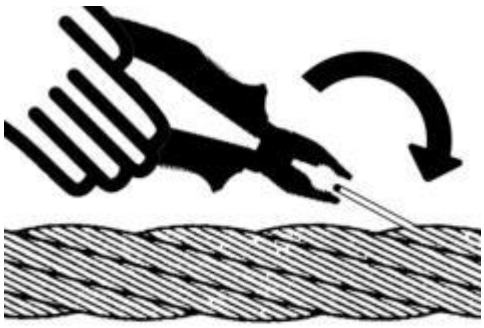
Wire break





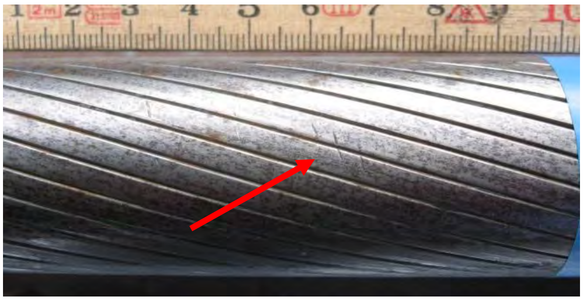
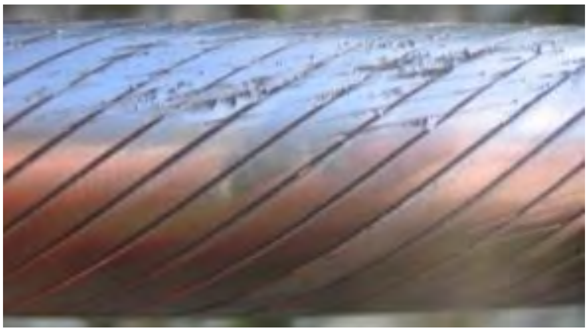
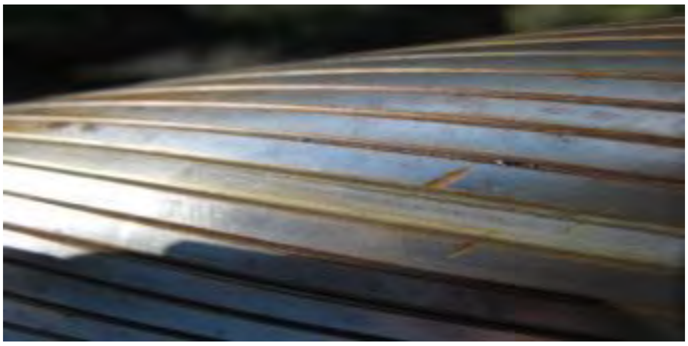




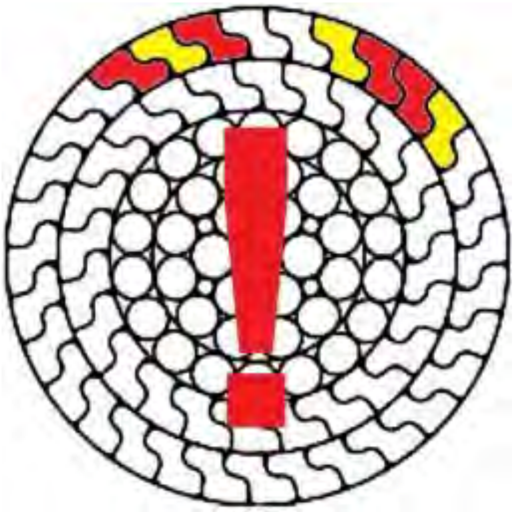



Distortions

Example rope damages on track ropes

Locked coil rope – hair lines / notches	
	
	
	
	

Locked coil rope – wire breaks



EN12927-6:2004 „Discard criteria“, §6.1.4: Local deterioration

„two adjacent broken outer wires of a locked coil carrying rope (track rope) or two broken wires separated by one unaffected single wire“